# Use of Alternative Fuels

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## SUMMARY

The use of alternative fuels (AF) in cement kilns can save costs and contribute to the solution of environmental problems. The paper on hand concentrates on technical and environmental aspects.

Rules on how to use alternative fuels and possible impacts are given. Practical examples are attached (flowsheets).


## 1. INTRODUCTION

- Burning of alternative fuels (AF) in cement kilns offers unique advantages from an environmental point of view (high temperatures, long retention, no solid residues, no increase of emission, overall reduction of $CO_2$ emission).
- Using alternative fuels saves costs. Two main factors contribute to this
  1) Thermal substitution rate (there are technical limits)
  2) Low or even negative energy price (USD per GJ) for AF's
- Logically only fuels that are significantly cheaper than conventional fuels (USD per GJ) can create cost savings. However, even if AF's are cheaper all the additional costs involved have to be considered to make it profitable (preparation, additional production costs, maintenance, reduction of OEE, etc.)
- Within the Holderbank, Group 52 plants are using significant amounts of AF. The average thermal substitution rate of all 105 plants is 12.3% (1998).
  The fuel cost substitution rate (which is not the same as thermal substitution rate) is not yet being reported and the difficulty is to get an objective and fair consideration of all additional costs involved. From the basic principle cost substitution rates of over 100% are possible at negative fuel prices, but so far very exceptional.

## 2. TYPES OF ALTERNATIVE FUELS

By definition, fuels, which are not traded in the normal fuel market, are considered as "alternative fuels". Petcoke e.g. is not classified as "alternative fuel" and is listed in a separate application list (not treated here).

Alternative fuels can be roughly divided into solid and liquid fuels (gaseous is negligible).

Whether it is simple or difficult to use an alternative fuel depends much on its physical properties. E.g. it may be very simple to use waste oil which has been purified by the supplier. On the other hand it is impossible to use e.g. raw domestic refuse directly as solid fuel, because it is of poor quality and very inhomogeneous. The only practical way to burn it in a cement kiln is a sophisticated pre-treatment to produce RDF (refuse derived fuel).

Table (1) shows a list of alternative fuels in the order of their CV compared to conventional fuels. The calorific value alone does not directly indicate the potential to save costs. E.g. waste tires are as good as coal from the viewpoint of CV but require expensive handling and tend to cause negative impacts on the kiln process, so an adequate compensation must be included in the price (disposal fee).

**Table 1** **Various Alternative and Conventional Fuels, grouped according to their CV**

(*= conventional fuel)

| Material | CV [MJ/kg] net |
|---|---|
| Pure polyethylene [3] | 46 |
| * Light oil | 42 |
| * Heavy oil | 40 |
| Tar (by-product) | 38 |
| Pure rubber (without inert material) | 36 |
| * Anthracite | 34 |
| Aluminium metal [1] | 31 |
| Waste oils, various refinery wastes | 30 to 40 |
| * Petcoke | 33 |
| Waste tires | 28 to 32 |
| * Bituminous coal (low ash) | 29 |
| * Bituminous coal (high ash) | 24 |
| Liquid mix (CSS from SCORIBEL or SYNFUEL from Safety Kleen) | 20 to 30 |
| Landfill gas | 16 to 20 ($MJ/Nm^3$) |
| Acid sludge, acid tar (from oil reprocessing) | 16 to 22 |
| * Lignite (10% moisture) | 16 to 21 |
| Pot liners (from aluminium smelter) | 20 |
| PVC [3] | 19 |
| Palm nut shells (10% moisture) | 19 |
| Pressed olive cake | 18 |
| Dried wood, bark, saw dust (10% moisture) | 16 |
| Rice husks (10% moisture) | 16 |
| Car shredder wastes | 15 |
| RDF (from domestic refuse, 10% moisture) | 15 |
| Animal meal | 15 |
| Cardboard, paper (air dry) | 15 |
| Impregnated saw dust (25% moisture) | 10 to 12 |
| Dried sewage sludge (10% moisture) | 10 |
| Fuller's earth (from oil purification, LD actual) | 10 |
| Domestic refuse (30% moisture) | 8.5 |
| Dried sewage sludge (30% moisture) | 7.5 |
| Pure iron [2] | 7.5 |

1) Al metal may occur e.g. in composite packaging wastes and is oxidised to $Al_2O_3$

2) Fe metal occurs e.g. in waste tires and is oxidised to $Fe_2O_3$

3) Usually not in pure form, but contained in mixed plastics

# 3. UTILIZATION IN CEMENT KILNS

## 3.1 List of Applications

Practical experience and practical applications are the key items in the field of alternative fuels. It is important to know where practical applications or tests have been realized and obtaining the experience from such cases.

At HMC/TPT a database on practical applications or test or projects in context with alternative fuels is used and updated regularly. It includes more than 200 plants inside and outside of the Holderbank Group. A typical printout for the first few examples looks as follows:

**Database Alternative Fuels** — "HOLDERBANK" Process Technology

| COMPANY | WORKS | CODE | COUNTRY | AREA | ALTERNATIVE FUELS |
|---|---|---|---|---|---|
| Ciments d'Obourg S.A. | Obourg | OB | B | 1 | Coal wastes(DB 822), RDF(DB 829/P new), sludge coal, impregnated sawdust, liquids/solvents(via SCORIBEL), "déchets banal" ("mid kiln) |
| "Holderbank" Cement und Beton | Rekingen (S) | RK | CH | 1 | Wood wastes/waste timber(Aug 94-end 97) |
| "Holderbank" Cement und Beton (form.PCW) | Siggenthal | SG | CH | 1 | Waste tires, dried sewage sludge (Cap.25000 t/a), Plastics(T), animal meal |
| "Holderbank" Cement und Beton (form.SCB) | Eclépens | EC | CH | 1 | Waste tires, oil-contaminated soil, residue from anode production(T), RDF(from SORVAL), sawdust |
| "Holderbank" Cement und Beton (form.SCB) | Roche(S) | RO | CH | 1 | Filter tar(DB 489), charcoal tar, anthracite dust from Alu-indust(P), solvents, waste oil |
| Bündner Cement AG | Untervaz | UV | CH | 1 | Waste oil, dried sewage sludge, fuller earth (temp), oil contaminated soil, distillation residues, plastics, animal fat |
| Vigier Cement AG | Reuchenette | RE | CH | 1 | Waste oil, liquids/solvents/chlorinated(from Basel), wood wastes(P), plant wastes via (small) gasifier, Dried sewage sludge |
| CEVA Prachovice | Prachovice | PR | CZ | 1 | Waste oil |
| Alsen-Breitenburg GmbH | Lägerdorf | LD | D | 1 | Waste tires(S/Lepol), fuller earth(DB 102/MF and SF), shredder(S), RDF(T/S), waste oil, high viscosity residue from distillation, carbon bearing flyash, paper sludge, rubber chips |
| Nordcement AG | Hardegsen (S) | HD | D | 1 | Landfill gas, waste oil(P), waste tire granulate(T) |
| Nordcement AG | Hoever | HV | D | 1 | Waste tires, tire granulate(P), fuller earth(T/S) |
| HISALBA | Carboneras | CS | E | 1 | Contam. vegetable oil (single action) |
| HISALBA | Jerez | JE | E | 1 | Waste oil |
| HISALBA | Lorca | LO | E | 1 | Waste oil, solvents, waste tires (mid kiln) |
| HISALBA | Torredonjimeno | TD | E | 1 | Pressed olive cake (S) |
| Groupe Origny S.A. | Altkirch | AL | F | 1 | Liquids, Tires, solids(MF) |
| Groupe Origny S.A. | Champagnole(S) | CN | F | 1 | Tar(residue from distillation), liquids/solvents/waste oil(via SCORI) |
| Groupe Origny S.A. | Dannes | DN | F | 1 | Landfill gas (P), waste tire chips(T,S), impregnated sawdust |
| Groupe Origny S.A. | Héming | HE | F | 1 | Waste tires(T), Solids"DIB", car shredder wastes"RBA"(T), solvents |
| Groupe Origny S.A. | Lumbres | LU | F | 1 | Liquids, solids, sawdust |
| Groupe Origny S.A. | Origny (S) | OY | F | 1 | waste oil, high viscosity liquids, coal sludges |
| Groupe Origny S.A. | Rochefort | RF | F | 1 | Tar(residue from distillation), liquids/solvents/waste oil(via SCORI) |

## Database Alternative Fuels

"HOLDERBANK" Process Technology

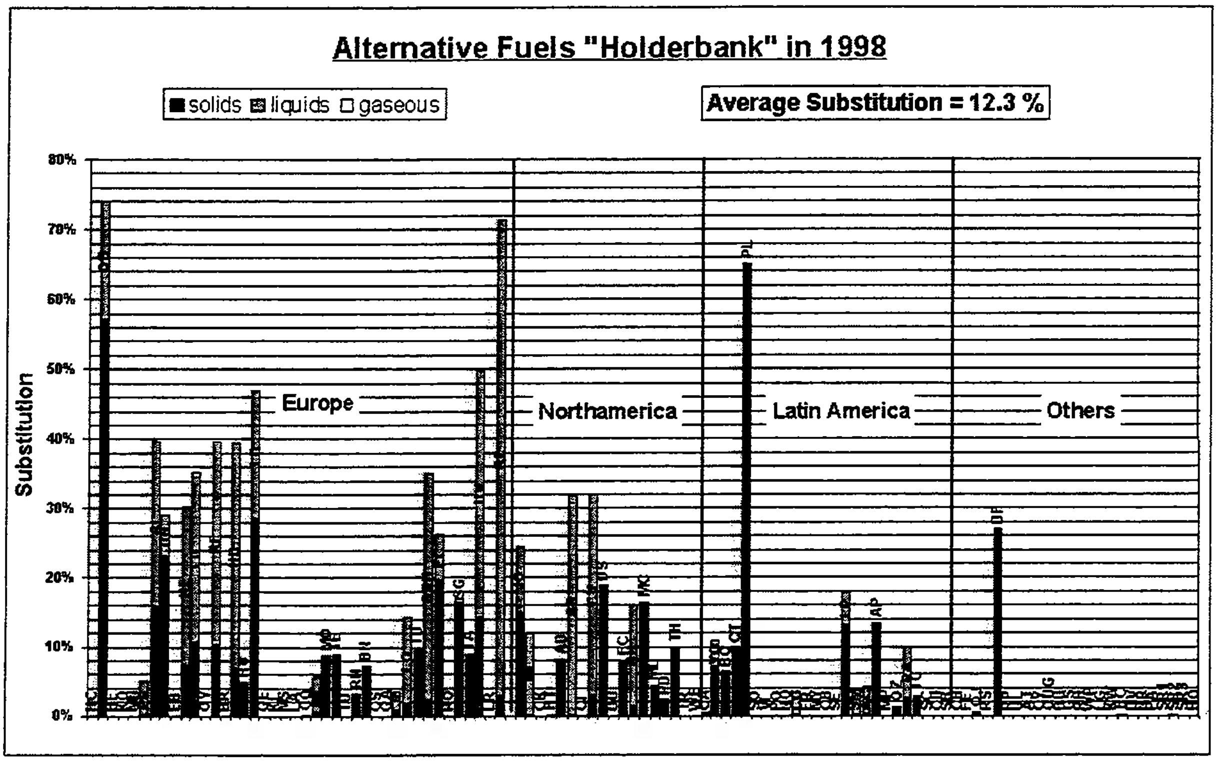
| COMPANY | WORKS | CODE | COUNTRY | AREA | ALTERNATIVE FUELS |
|---|---|---|---|---|---|
| Cementeria di Merone | Merone | ME | I | 1 | Fuller earth(DB 101,650), pitch("Laboni"), refinery wastes, waste oil(S), acid sludge(S/DB 878), liquids, highly viscous oil "bitoil" (P) |
| Cementeria di Merone | Cassago | CO | I | 1 | Graphite |
| Cementeria di Merone | Ternate | TE | I | 1 | Rubber chips, RDF, Plastics |
| Cementeria di Merone | Morano | MO | I | 1 | Plastics, RDF, tire chips |
| Hirocem A.S. | Rohoznik | RN | SQ | 1 | Waste oil, waste tires, impregnated saw dust |
| St. Lawrence Cement, Inc. | Beauport (S) | BP | Canada | 2 | Waste oil, spent potliners (T), sawdust, paper sludge(P) |
| St. Lawrence Cement, Inc. | Joliette | JO | Canada | 2 | Wood wastes(T,P), waste oil(baseline test 1990), waste tires(mid kiln) |
| St. Lawrence Cement, Inc. | Mississauga | MI | Canada | 2 | Waste oil(DB 103), liquids(chlorinated), PCB(S/DB 496), solvents, RDF(P) |
| Holnam | Ada | AD | USA | 2 | Waste tire chips, TDF, whole tires (Mid kiln, P) |
| Holnam | Artesia | AR | USA | 2 | Liquids (WDF) |
| Holnam | Clarksville | CV | USA | 2 | Liquids(also chlorinated)/solvents, Synfuel(DB1072), waste tires chips |
| Holnam | Devils slide | DS | USA | 2 | Tires/TDF < 2", wastes from diapers prod. |
| Holnam | Dundee | DU | USA | 2 | Waste oil, liquids(also chlorinated)/PCB(S/DB 238), waste tires chips(T), TDF(P) |
| Holnam | Holly Hill | HH | USA | 2 | Residues fro Alu-smelter (pot liners, filter tar,S), domestic refuse/RDF(T), liquids, synfuel(DB1072), tires/TDF < 3/4" (P) |
| Holnam | Mason City | MC | USA | 2 | Waste tires (P, mid kiln), tire chips |
| Holnam | Portland | PD | USA | 2 | Waste tires (TDF) (P), Asphalt(gilsonite) (P) |
| Holnam | Theodore | TH | USA | 2 | Waste tires chips |
| Holnam (Holnam Texas L.P.) | Midlothian | ML | USA | 2 | Waste tires chips(via PC) |
| Independent Cement Corporation | Hagerstown | HT | USA | 2 | Waste oil(permit P), waste tires(P complete+TDF) |
| Juan Minetti S.A. | Yocsina | YO | Argentina | 3 | Plastic-chips (T), liquids(T,P) |
| "Holdercim" Brasil S.A. | Pedro Leopoldo | PL | Brasil. | 3 | Charcoal from steel production, heavy oil with high viscosity, liquids, solids in pales and big bags, sawdust/RESOFUEL (P), waste tires (P) |
| "Holdercim" Brasil S.A. | Barroso | BO | Brasil. | 3 | solids |
| "Holdercim" Brasil S.A. | Cantagalo | CT | Brasil. | 3 | Solids, tar |
| CIMINAS - Cimento Nacional de Minas S.A. | Sorocaba(S) | SO | Brasil. | 3 | Rubber/waste tires(S, small size in SZ) |
| Industria Nacional de Cemento S.A. | Cartago | CG | Costa Rica | 3 | Palmnut shells(Coquitos,Olotes), wood wastes, fresh wood(P) |

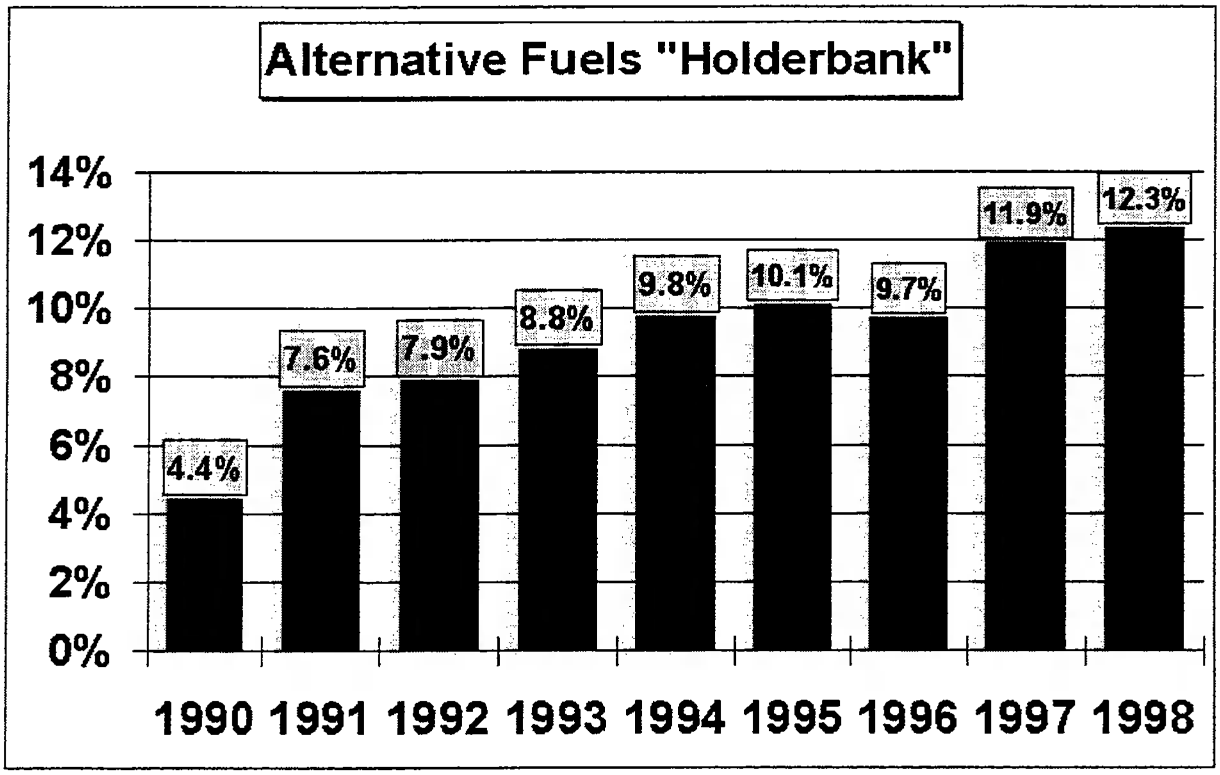
## Database Alternative Fuels

"HOLDERBANK" Process Technology

| COMPANY | WORKS | CODE | COUNTRY | AREA | ALTERNATIVE FUELS |
|---|---|---|---|---|---|
| Cementos Progreso S.A. | La Pedrera | LP | Guatem. | 3 | Liquids |
| Cementos Progreso S.A. | San Miguel | SM | Guatem. | 3 | Waste oil |
| Apasco S.A. | Ramos Arizpe | RA | MEX | 3 | Liquids, tire chips |
| APASCO S.A. | Acapulco | AC | Mex | 3 | Waste oil |
| Apasco S.A. | Apaxco | AP | Mex | 3 | Waste tires, liquids |
| Cementos Caribe C.A. | Cumarebo | CU | Venezuela | 3 | Refinery wastes (lodos) (P) |
| Milburn New Zealand Ltd. | Westport | WP | Neuseeland | 5 | Ship slops, waste oil(P) |
| Iligan Cement Corp. | Kiwalan | KW | Philipp. | 5 | Wood wastes |
| Alpha Cement | Dudfield | DF | RSA | 6 | Waste tires (T) |
| Eiberg Cement | Kufstein | - | A | F1 | Waste tires |
| Gmundner Zementwerke Hans Hatschek AG | Gmunden | - | A | F1 | Waste tires chips(DB 597), wood chips(T/S), waste oil/liquids |
| Leube Zement | | - | A | F1 | Plastic, waste tire chips |
| Perlmooser Cement | Mannersdorf | - | A | F1 | Waste tires, plastics(T) |
| Perlmooser Cement | Retznei | - | A | F1 | Waste tires |
| Perlmooser Cement | Rodaun | - | A | F1 | Waste tires |
| Schretter & Cie. | Vils | - | A | F1 | Waste tires |
| Wieterdorfer & Peggauer Zementwerke | Peggau | - | A | F1 | Waste oil, solvents |
| Wietersdorfer & Peggauer Zementwerke | Wietersdorf | - | A | F1 | Waste tires, liquids, plastics (T) |
| Wopfinger Stein-& Kalkwerke | Waldegg | - | A | F1 | Paper-sludge from paper ind. |
| CBR | Antoing | - | B | F1 | Waste tires chips (<20mm in PC), Installation for paper,cardboard,wood("BPC"),with grinding(S),plastics(PET),car-shredder("RBA") |
| CBR | Harmignies | - | B | F1 | Liquids ("blanfuel") (P) |
| Cimenteries CBR | Lixhe | - | B | F1 | Waste tires, sawdust containing liquids, paper wastes, liquid wastes |
| Jura-Cement | Wildegg | - | CH | F1 | Waste tires, Plastics(T), Gasification waste tires/wood (T,P) |
| Portlandcementwerk AG Olten | Olten | - | CH | F1 | Oil-contaminated soil, waste oil(temp) |
| Anneliese Zementwerke AG | Werk I/II | - | D | F1 | Landfill gas, waste tires(DB 827), pressed refuse(T) |

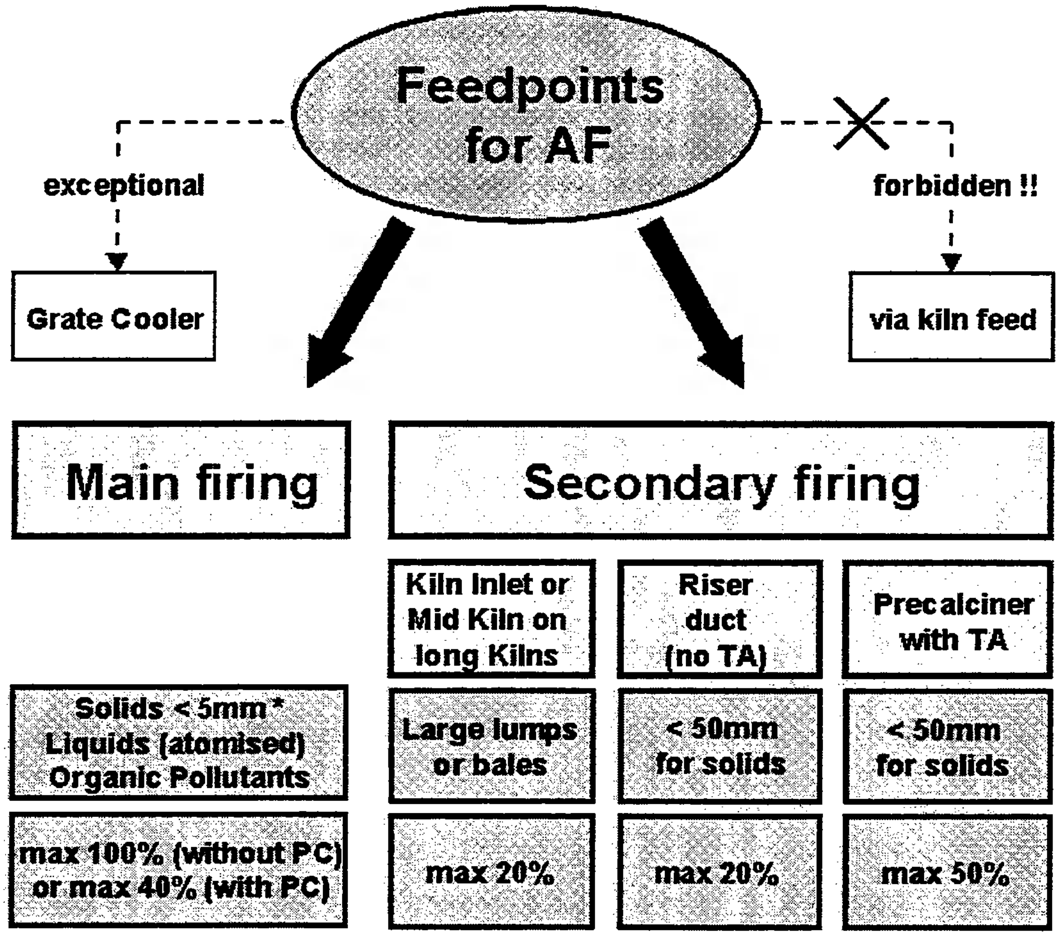
**Fig. 1 „Holderbank" Alternative Fuels**



## 3.2 Feedpoints for Alternative Fuels

**Fig. 2 Feedpoints for AF**




* **Note to solids into mainfiring:**

**solid granulometry depends also on particle shape and weight.**
**Very thin solids (foils) can be up to < 50mm.**
**Long kilns (L/D > 20) allow coarser granulometry**

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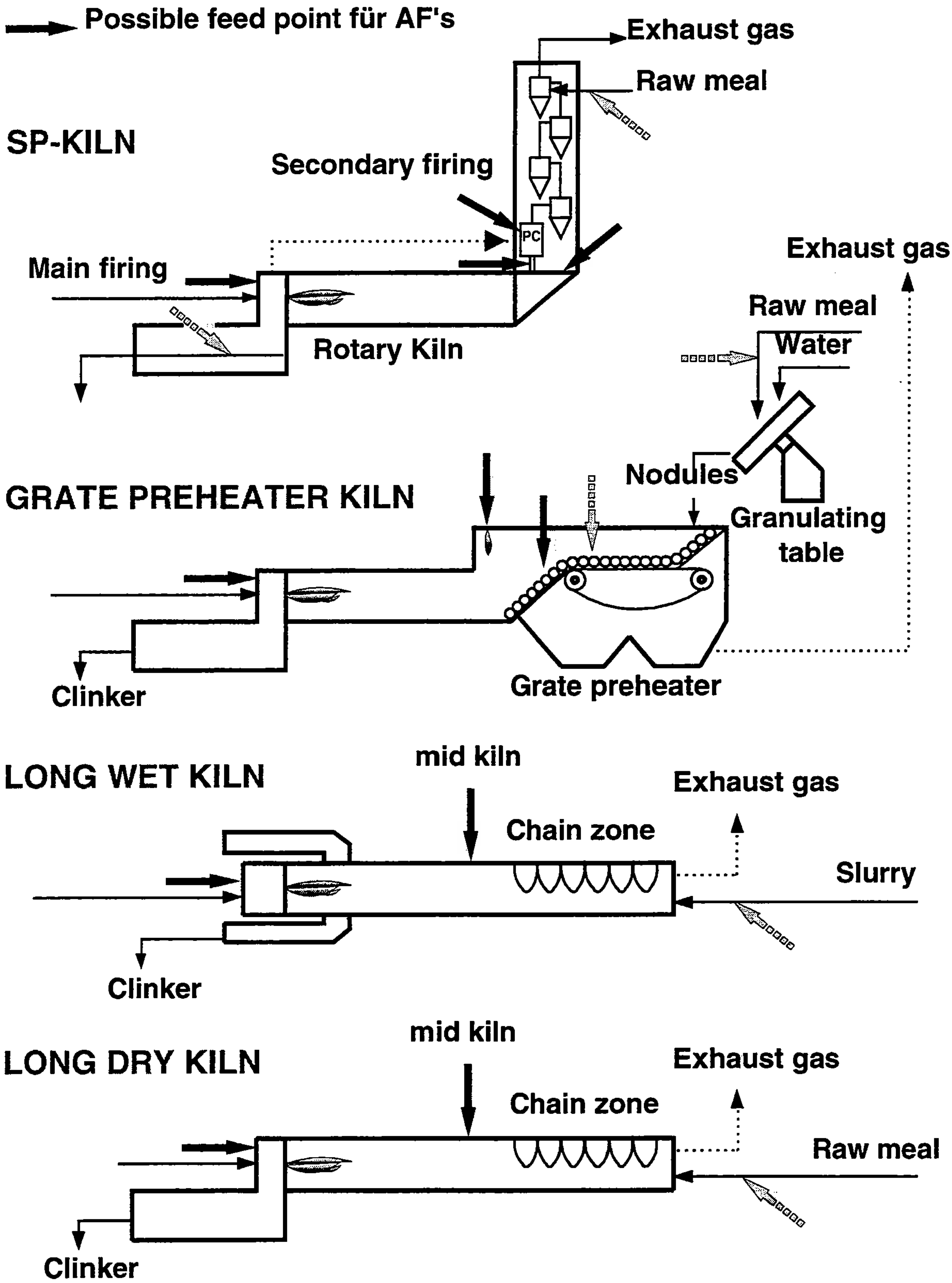
Process Technology

Regarding the selection of feedpoints the following comments apply:

- Solid fuels of large size tend to produce more combustion problems especially when pushed to high substitution rates. So the practical substitution rates are often below the above optimum figures. Remedy is possible by better preparation (size reduction), if economically feasible.
- In exceptional cases solid fuels can be transferred into a combustible gas by means of a process integrated gasifier. The gasifier is then the "ultimate preparation" which allows a comparatively easy burning. Since such solutions are expensive they are reserved to special applications (the example of tire gasification is mentioned in this paper).
- The feed point via kiln feed is forbidden because of the emission problems during preheating (VOC, CO). This feed point is reserved for alternative materials with no organics. The only exception would be kiln systems where the kiln feed enters the combustion zone without preheating (one stage precalciner kiln at FC) or kilns with VOC removal system (carbonfilter SG, oxidiser at DU).

**Fig. 3** **Feed Points for Alternative Fuels to Cement Kilns**



Regarding the different kiln systems the following rules apply:

A Circulation Phenomena

- Kiln systems with cyclon suspension preheater and without bypass are most sensitive to circulating phenomena. If the following criteria are not respected, the AF use will cause severe problems or will fail
  - Keep total chlorine input below 200 – 300 mg/kg clinker (from all fuels and raw materials). If this limit is exceeded a bypass is required. The cyclone preheater without bypass is not forgiving excessive Cl input, it will just plug.
  - Keep sulfur cycles under control! Unlike Cl the most critical factor is not the possible sulfur input by AF but the impact of poor AF combustion on sulfur volatilisation. This will promote a high sulfur cycle and sulfur pluggings. Remedies: improve combustion, higher O2 at kiln inlet, enhanced preheater cleaning.
- Kiln systems with grate preheater (Lepol) are of similar sensitivity to circulating phenomena as cyclone preheater kilns. Condensation of volatile elements in the nodule bed on the preheater can disturb its permeability and thus the kiln operation.
- Long dry kilns or long wet kilns are more forgiving in terms of circulating phenomena as they have no critical narrow cross sections. However, rings and build-ups in the rotary kiln also occur but it takes longer until they grow to a critical size. If the kiln system works with 100% dust reintroduction the sustainable chlorine limit is the same as on a cyclone preheater kiln (200 – 300 mg/kg clinker).
  The difference to the cyclone preheater kiln is that it is easy to realize a valve for chlorine on a wet kiln if the kiln is equipped with an EP dedusting. This allows to extract a highly enriched fine dust selectively that removes chlorine effectively when being discarded. Like that up to 5000 mg/kg cli chlorine input can be handled. In this case the discarded dust causes an additional disposal problem, because it cannot be added to the cement due to the chlorine limit for cement (0.1% Cl).

Chlorine limit

Regarding the chlorine input the following diagram helps to get a quick overview of what can be accepted as total input if then chlorine would come only from AFR (whether it's a Fuel or a Raw material does not matter here).

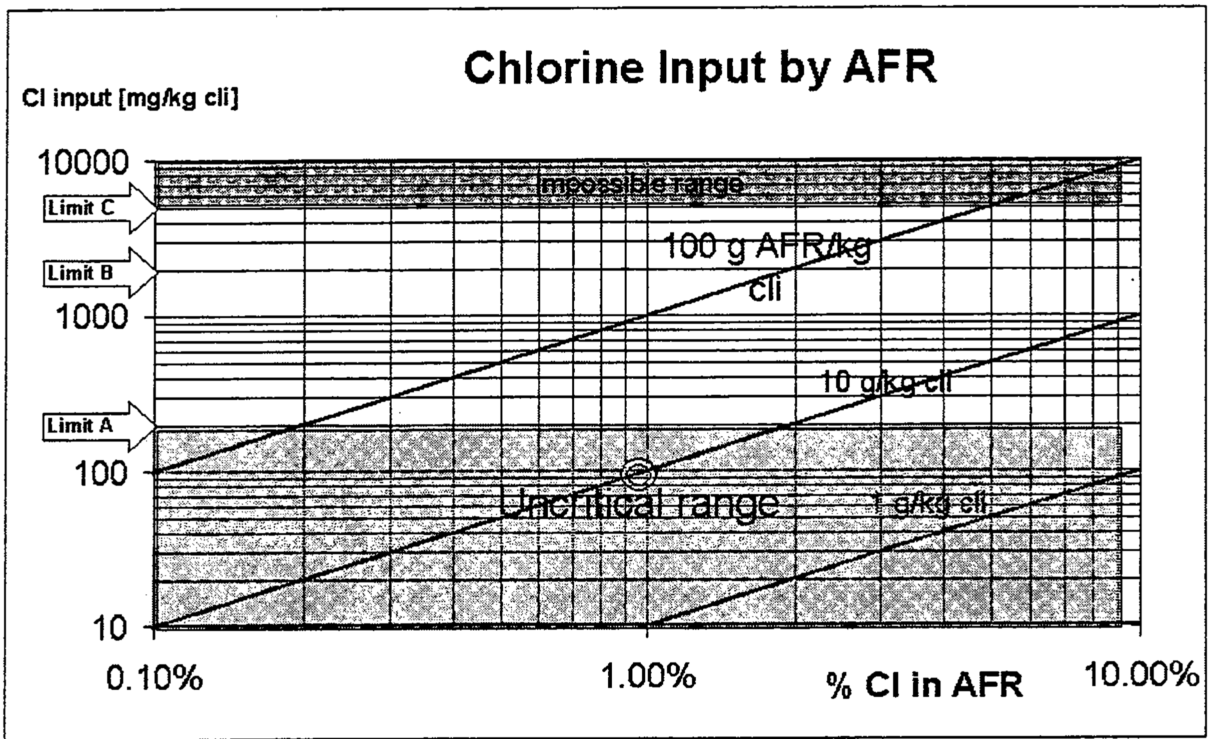
The following limits apply:

| | |
|---|---|
| Limit A: | Normal SP kiln with completely closed dust loop |
| Limit B: | SP kiln with some 20% bypass or wet kiln discarding medium dust quantities |
| Limit C: | Maximum possible for wet kiln discarding high dust or SP kiln with 100% bypass |

Example:

An AFR with 1% Cl at a relative input of 10 g AFR per kg clinker creates an input of 100 mg Cl/kg cli, which is not critical (assuming no other inputs of Cl).

**Fig. 4 Chlorine Input by AFR**




B Temperature and gas residence line

If stable toxic organic compounds in AF's are an issue the main kiln features for their destruction have to be known.

- Main firing
  - Flame temperature 1800 – 2000°C
  - Total gas residence time in rotary kiln depends on kiln system as follows
    - short kiln (2 support) approx. 3 sec.
    - normal SP/PC kiln more than 5 sec.
    - long wet or dry kiln more than 10 sec.

  So typically a gas residence time of approx. 5 sec. above 1200°C can be expected.
- Secondary firing (no PC), with unextended riser duct 1 sec. above 820°C
- Precalciner with tertiary air 2-4 sec. above 860°C (in case of hot spot design peaks up to 1200°C)

For optimum combustion and safe destruction of stable organics only the main firing shall be used. Example: waste oil that is contaminated with traces of PCB.

Other feedpoints are reserved for less critical AF's or if they are used for critical substances tests may become necessary. To avoid extensive tests it is often easier to select the main firing.

Finally the above temperatures are not valid for start up or upset conditions so critical AF's should only be used under normal operating conditions.

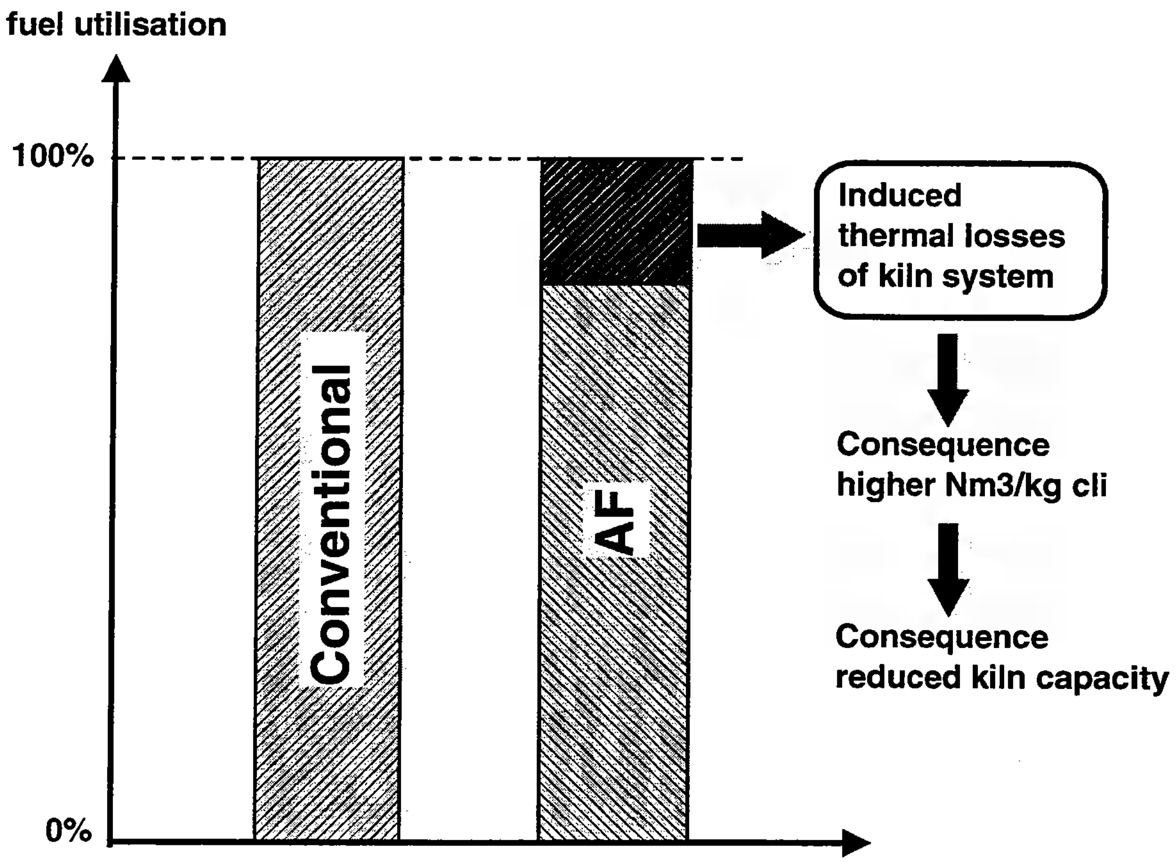
### 3.3 Substitution effect and potential capacity loss

Introduction

If low grade fuels are used to substitute high grade conventional fuels (coal, oil, gas) the kiln will react with certain effects that will increase the thermal consumption and decrease the maximum kiln capacity. Both phenomena are related to each other.

If the energy costs for AF's are low or even negative one may think the increase in heat consumption is not that negative because the additional consumption can be covered with low cost AF. This is only half the truth. If maximum production is required at the same time every ton of clinker that cannot be produced means a financial loss. Roughly every one % increase in heat consumption also means one % loss in potential kiln capacity. And if kiln availability is lower due to AF's the OEE can decrease even further.

**Fig. 5 Conventional Fuel versus AF**



Factors for increased heat consumption

Why can AF's increase the thermal losses on a cement kiln system and thus create "induced losses"? There is a defined number of reasons that contribute to such effects as follows:

1) High water content in AF

   A high water content increases both exhaust gas quantity and exhaust gas temperature.

   Consequence: increased heat loss in the exhaust gas that needs to be compensated by more fuel.

2) High ash content in AF

   A high ash content reduces the amount of kiln feed that passes through the preheating zone and decreases the heat recovery by kiln feed. The exhaust gas temperature increases.

   Consequence: increased exhaust gas loss that needs to be compensated by more fuel.

   Note: the same effect happens if cold raw material is added directly into the precalciner.

3) Reduced combustion properties

   Certain AF's have poor combustion properties because of too coarse granulometry. Depending on the control strategy this can mean increased CO losses or increased $O_2$ level to compensate this.

   Example: whole tires at kiln inlet

   Consequence: No matter what the strategy is, the final result is always a higher energy loss in the exhaust gas, which has to be compensated by more fuel.

4) Fluctuating AF feed (at good combustion properties)

   Fluctuations in AF energy input can result from

   - Inhomogeneous AF properties (CV)
   - Fluctuations of the dosing rate due to more difficult handling properties

   Both items have the same impact as for item 3). What happens if a temporary excess of energy input occurs? Either a CO loss is generated or the $O_2$ has to be set so high that no CO is generated.

   Consequence: same as in case 3).

   (The difference to case 3) is that this can happen even with fuels that have good combustion properties.)

   Example: poorly homogenized liquids or poor performance of dosing system.

5) Cold air introduction

   Solid coarse AF usually need a high amount of air for pneumatic injection or an air leakage can occur at a poorly sealed feed chute for AF. This has the same effect as an increase of the primary air on a burner.

   Consequence: Inleak of additional cold air (due to AF) causes higher fuel consumption.

6) More circulation phenomena due to AF

Circulation phenomena do not only occur because AF can introduce circulating elements but also be a result of poor combustion (local CO formation). Although the evaporation and condensation of circulating elements induces a heat transport from the hot zone to the colder zones, the direct effect on balance heat consumption is not that critical. What really disturbs is the unstable kiln operation, which results in reduced availability and higher average fuel consumption.

Consequence: reduced availability due to unstable operation/stoppages and increased average fuel consumption.

The majority of the above factors (1, 2, 4 and 5) can be quantified of predicted and the other factors are based on experience. (One of the services that can be provided by HMC/TPT.)

Practical substitution effects (examples):

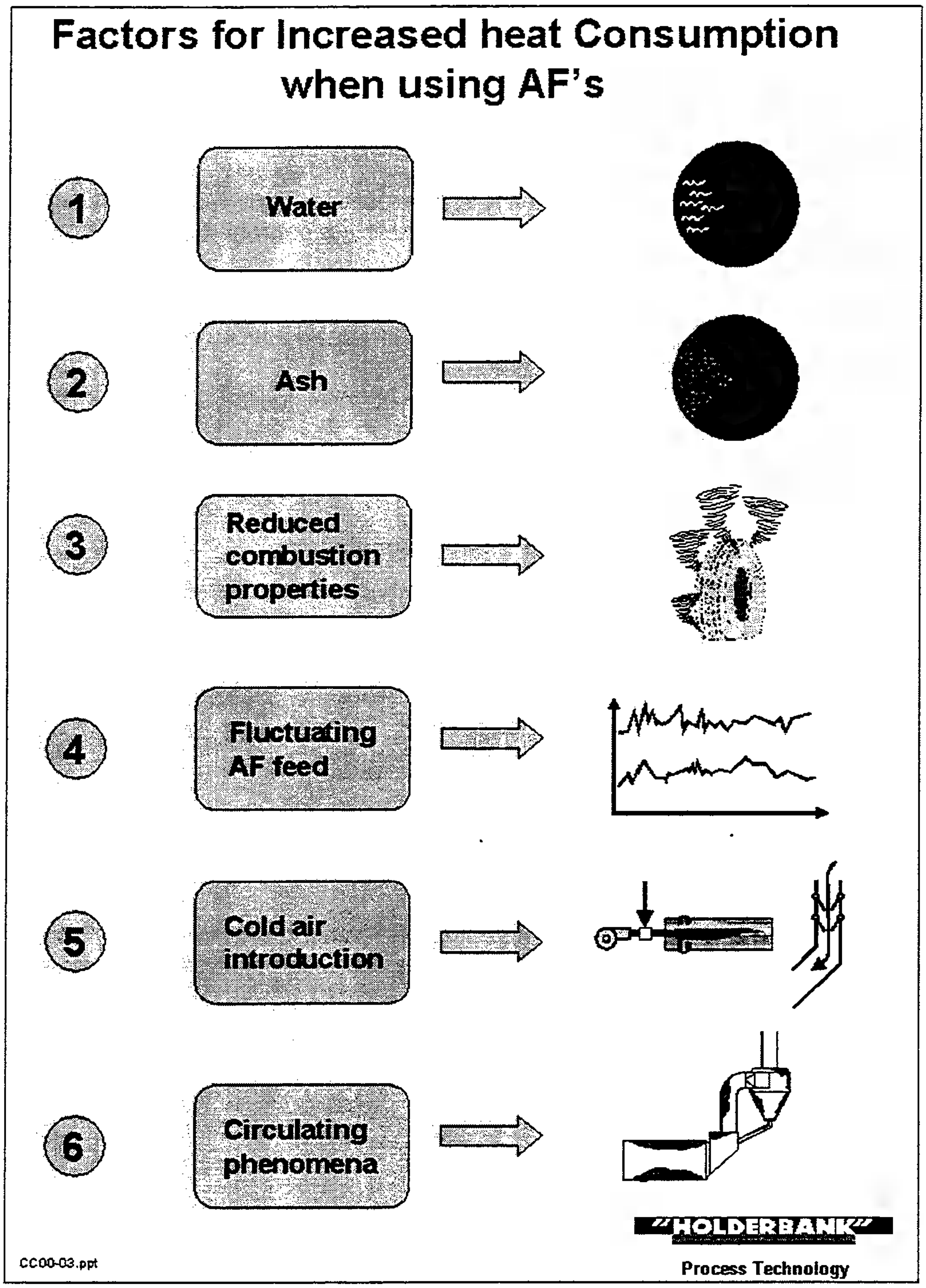
- Liquids with < 10% $H_2O$ and good homogeneity 95 – 100%
- Very low grade waste as raw domestic refuse 70% or lower

So the substitution effect would be typically between 70 – 100% as long as the applications are approached in a engaged and professional way and no unusual difficulties occur. For low grade AF (high ash, high water, coarse, inhomogeneous) the lower limit of 70 % would be typical.

Conclusion

1. The potential fuel substitution value of an AF (USD/GJ) cannot be calculated by just using its net CV. A reduced effect of typically 70 – 100% can occur. This is only on basis of immediate additional thermal losses (not yet taking into account other costs that emerge when using AF).
2. When reporting the true heat consumption of a kiln, we have to accept higher consumption when using low grade AF's. Manipulating CV's for AF to get the same consumption (on paper) is physically incorrect and not a good reporting practise.
3. The potential capacity loss when using AF's is directly linked to the % increase in heat consumption. Increased heat consumption and possibly also reduced kiln availability can have an important impact on OEE.

**Fig. 6 Factors for Increased Heat Consumption**



## 3.4 Supply and Inlet Control

### 3.4.1 Organisation of supply

To get AF to the cement plant can be basically done in two ways:

1) Get AF directly from a waste source.
2) Get AF through a specialised company that prepares an adequate waste blend for the cement.

Both ways are being used. The possibility 1) is adequate for certain wastes that can be used with minimum or no pre-treatment before shipped to the cement plant. A standard example would be tires.

The possibility 2) is a more professional approach, which involves also better integration in the whole waste market. Specialized companies emerged in the previous years and their number is still growing. Classical examples were

- SCORI (France)
- SCORIBEL (Belgium/Obourg)
- SYSTECH (USA/Lafarge)
- SAFETY KLEEN (USA/partly active for Holnam)

With the exception of Safety Kleen all these organisations were controlled by the cement industry.

The new companies that have emerged within Holderbank recently are mostly orientated on the SCORIBEL/Obourg model. From a technical viewpoint of a cement plant these companies provide the following functions:

- Allocating adequate waste categories to the cement plant
- Control of properties
- Preparation/pretreatment
  (in particular blending/homogenising)

The preparation of waste into a useful cement kiln AF is done externally. This seems to become the preferred approach. The supply companies within Holderbank have a common platform: the VESTA Forum.

### 3.4.2 Delivery control

A delivery control at the cement plant is essential. In case of hazardeous wastes this is anyway a must (given by the permit) and this does not need to be explained further.

What is less obvious is that even harmless or non-hazardeous AF's need to be checked when delivered to the cement plant. The problem is that AF's can be contaminated with undesirable inpurities. Whether this happens intentionally or not, it needs to be excluded.

Examples:

- Waste oil

  The original motor oil would not be critical from its properties but the waste product that is finally delivered to the cement plant may be contaminated, e.g. with

  - Solvents (a small quantity of solvents decreases the flash point drastically and thus the safety can become a problem)
  - PCB (PCB contaminated oils have a high disposal fee and the cement kiln could be abused to get rid of them cheaply, PCB is not detectable by simple test methods)

- Waste tires

  When accepting waste tires it is mandatory to have a visual delivery control and the receiving area must not allow uncontrolled access for various suppliers. Some plants that believed they could do it without any control finally paid a high price because they were abused as a dumping area for non usable sizes, rims and other materials (for which they had to pay for the disposal).

- Chlorine

  It happened from time to time that suppliers came up with new solid waste mixes (RDF) or mixed plastics where they claimed very low chlorine contents. This is not always true, but difficult to disprove. There is in fact a problem that sampling of solid RDF is hardly representative and the chlorine analysis are often lower than the average bulk. So do not believe, but check what you get for chlorine, it could hurt your kiln operation.

### 3.4.3 Check-list for Properties of Waste Fuels

**Table 2 Checklist for Properties of Waste Fuels**

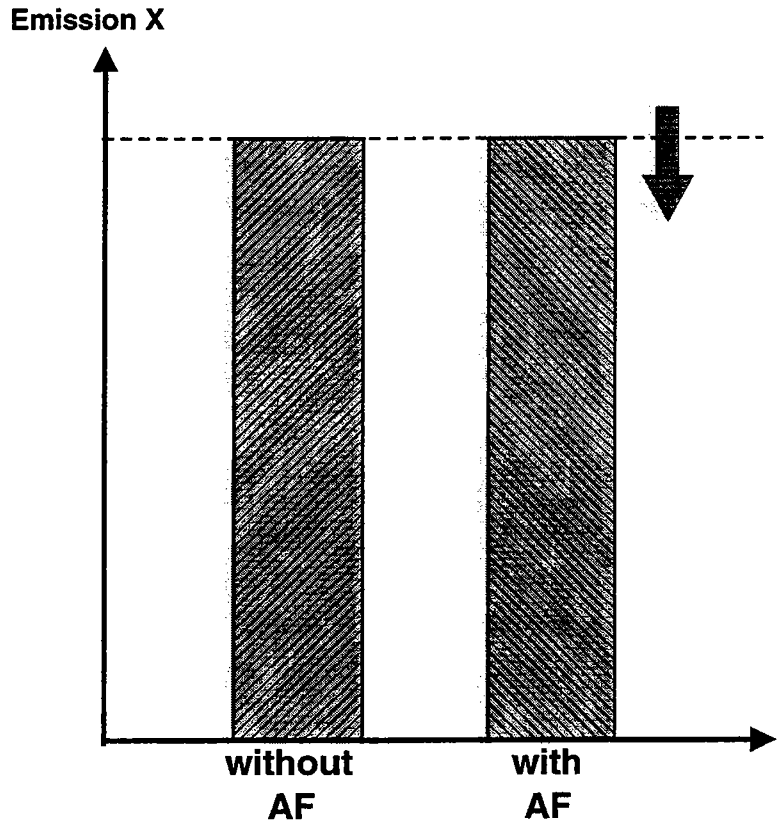
| | |
|---|---|
| • Type of waste | Name, trade name origin |
| • Physical state: | |
| solid | Size, form, grindability |
| liquid | viscosity at ...°C, |
| gaseous | impurities |
| solid/liquid | mixing proportions |
| • Density | $kg/m^3$ |
| • Calorific value (net) | MJ/kg |
| • Proximate analysis | Moisture, ash, volatiles, $C_{fix}$ |
| • Ultimate analysis | C, H, O, N, S |
| • Halogens | Cl, Br, F |
| • Ash composition | $CaO$, $SiO_2$, $Al_2O_3$, $Fe_2O_3$, $K_2O$, $Na_2O$, $P_2O_5$, etc |
| • Heavy metals | Hg, Cd, Tl, Be, As, Co, Cr, Pb, Zu, V, etc. |
| • Flashpoint | °C |
| • Explosivity | non-explosive |
| • Toxicity | toxic /non toxic, safety precautions, warnings |
| • Legal restrictions containing transport and storage | |
| • Storage | Chemical or natural degradation, putrefaction phenomena, segregations, precipitations, |
| • Corrosivity | Construction materials required |
| • Mixing possibilities | Mixing with oil, water, solvents |
| • Quantities to be used | min, max, average (now, in future) |
| • Fluctuations in quality | Quality specification |

# 4. EMISSIONS IN CONTEXT WITH ALTERNATIVE FUELS

## 4.1 Introduction

If alternative fuels are used to substitute conventional fuels the cement kiln emissions are often not increased and may even drop.

**Fig. 6 Emission influence AF**

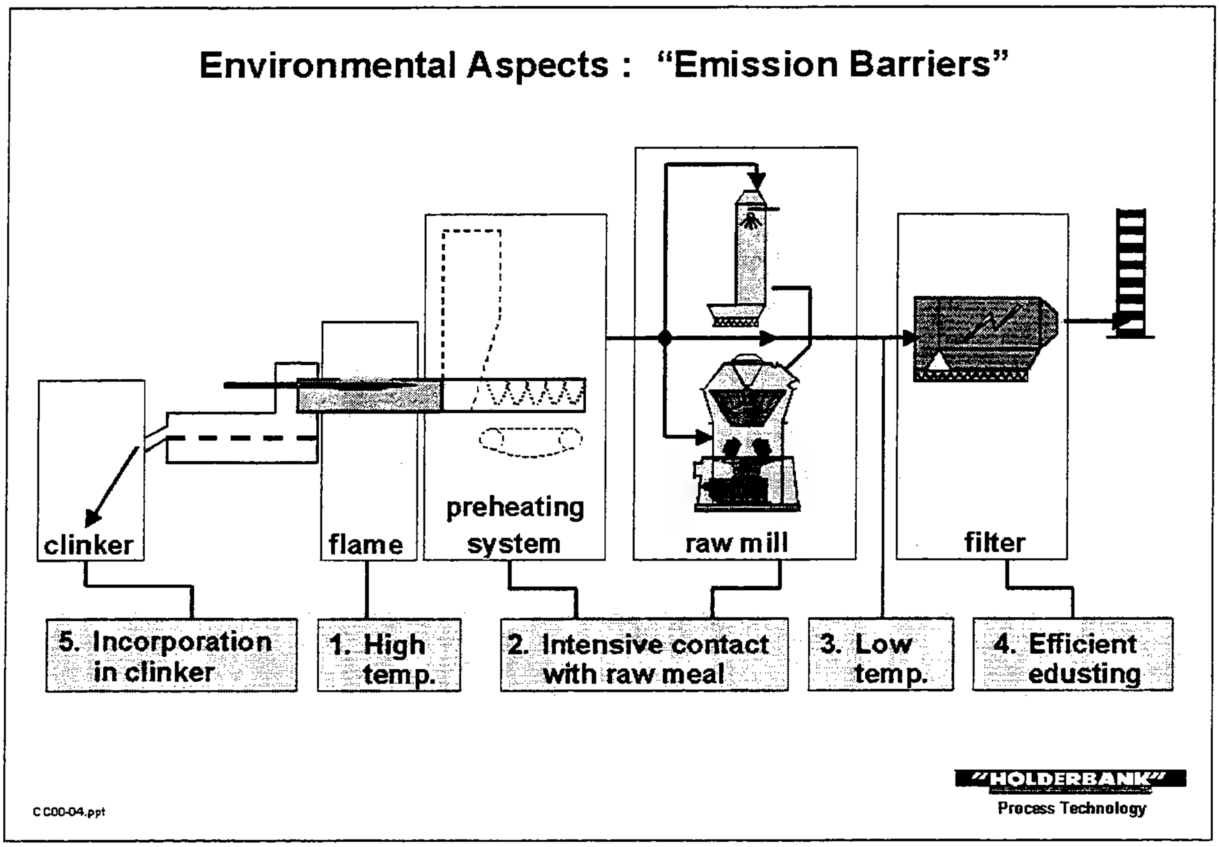



Emissions do occur but they are hardly caused by alternative fuels. Emission results mainly from the raw material and from the high temperature process (NOx) and the fuels have only a limited influence. E.g. the $SO_2$ emission on a suspension preheater kiln does not depend on the sulfur in the fuel. The difficult part can be how to handle the normal emissions if burning AF's attracts public interest and implies more stringent emission rules.

## 4.2 General Features of Cement Kiln Systems

"Barriers" which prevent toxic substances from being emitted or becoming harmful to the environment (see figure 7)

**Fig. 7** **Environmental Aspects: „Emission Barriers“**



## # 1 High incineration temperature

In the sintering zone flame temperatures of some 2000°C are required for process reasons. Even very stable organic compounds (e.g. PCB) are completely destroyed.

This argument does not apply for secondary firings.

## # 2 Contact with Fine, Dispersed Raw Meal

Intensive contact of gas and raw meal is required for process reasons (heat transfer). This produces gas purification through absorption of toxic compounds while contact occurs in counter-current pattern. Excellent retention of acid gases (e.g. HCl, $SO_2$) and also of most of the heavy metals is achieved in SP-preheaters and raw mills. The key is the contact of gas with fine suspended particles.

This does not apply for the bypass gas extraction, which must be considered e.g. in an emission estimate.

## # 3 Low Final Gas Temperature (favourable equilibrium)

Condensation or absorption on surface active raw meal reduces the concentrations of toxic elements according to the physical/chemical equilibrium. This effect strongly depends on the gas temperature. The lower the stack temperature the lower will be the equilibrium concentrations of the vapours of toxic compounds. Examples for very low stack temperatures are:

- Kiln gas after passing the raw mill (during combined operation) ~ 100°C

It is therefore possible to keep emission levels low, while the gases are passing the raw mill (argument #2 and #3 are equally important).

## # 4 Efficient Dedusting Equipment

The high absorption capacity of the kiln system avoids emissions but on the other hand can cause enrichments of the filter dust for certain elements that can reach the outer dust cycle (e.g. Tl). An efficient dedusting prevents enriched dust from getting into the atmosphere. Also no EP shut offs are acceptable. Moreover, excessive dust emissions have an over proportional negative psychological impact as all neighbours can see it.

## # 5 Safe Disposal of Trace Elements

Trace elements or heavy metals cannot be destroyed nor can they disappear. If they are fed into the cement clinkering process and are not emitted they must have an outlet. Unlike other incineration systems, which produce concentrated and often toxic by-products, a cement kiln with complete dust reintroduction offers the unique possibility to incorporate trace elements in the clinker production in diluted and immobile form. These trace elements occur in concentrations which are usually not different from clinker, which is produced without alternative fuels and they are not leachable (exception: hexavalent Cr during make up with water).

If the dust is not completely reintroduced into the kiln or if a bypass is required the above argument - in its simple form - is no longer true.

## 4.3 Special rules regarding emission behaviour on cement kilns

The reality with emission is usually too complex for a safe and accurate prediction. However, from an engineering point of view it is better to have some ideas or rules about the emission behaviour to roughly identify what could be critical or not.

- Low emission of Cl, F and Br, < 0.1% of balance input.
- Low volatile heavy metals are not critical. Emission usually < 0.1% of balance inputs.
- Medium or high volatile heavy metals can reach the outer dust cycle (Cd, Tl) or even escape in form of vaporous compounds (Hg). Whereas Cd and Tl are still below < 1% emission Hg can be emitted almost totally (again this depends on process conditions).
- $SO_2$ emissions are not depending on fuel sulfur in case of a SP kiln. Wet kilns however show a moderate influence by S on emissions.
- AF burning in the secondary firing usually decreases the NOx (0 – 30%).
- CO as discussed previously is often increased when using the secondary firing. Fluctuating energy input may also cause CO peaks.
- Virtually no organics result from AF burning (even in cases of CO formation it does not necessarily correlate with organics). The improper use of AF via kiln feed is of course excluded from this consideration.
- Dioxine/furan emissions on SP kilns are not critical in view of a limit of 0.1 ng $TE/m^3$. Again, there is no correlation with AF burning.

## 5. ADVANTAGES / DISADVANTAGES

Nowadays the destruction of wastes in special incineration plants is being improved e.g. by addition of more effective gas cleaning. Under this aspect the question may arise whether it still makes sense to incinerate wastes in cement kilns instead of in special incinerators. To answer this question the advantages and disadvantages of a cement kiln must be compared as follows:

| Advantages | Disadvantages |
|---|---|
| Possibility of high temperature incineration (up to 2000°C) which destroys toxic organic compound completely | |
| The majority of heavy metals can be captured at > 99.9% in the kiln system (absorption by raw meal) | Some limitations have to be considered, e.g. Hg, Tl, Cr |
| Acid gases are retained efficiently (e.g. no HCl emission) | Because of kiln internal circulation phenomena, cement kilns and especially SP-kilns cannot accept high inputs of chlorine |
| No solid residues occur because the ash is incorporated in the clinker. No landfill is required | In the case of wet kilns or bypass installations solid residues in the form of dust may need disposal |
| If the necessary rules are observed there will be no influence on emissions and clinker quality | For psychological reasons some customers may not accept cement which is produced by using „waste" |
| No necessity for a new incinerator since the cement kiln is already existing | |
| High environmental awareness helps to allocate certain wastes to cement plants | Realization of a project may be difficult and time consuming at the level of public discussion and obtaining of permission |

# 6. PRACTICAL APPLICATIONS

## 6.1 Waste Tires

Energy potential

- Calorific value (depends on quantity of steel included) 28 to 32 MJ/kg

Comparison for an industrialized country (per capita):

| | | | |
|---|---|---|---|
| a) Energy required to burn clinker at 500 kg cement/cap. a | (at 3.6 MJ/kg) | = | 1800 MJ/a cap. |
| b) Energy from waste tires at 6 kg tires/cap. a | (at 30 MJ/kg) | = | 180 MJ/a cap. |
| Theoretical overall fuel replacement (if tires were fully available for cement industry) | | | 10% |

Conclusion:

Tires are an important energy source and so far the most frequent application of AF. The practical attractivity depends on the disposal fee that is available. Current values (in different areas) range from 0 – 60 USD/t.

Typical Composition of Tires

| **Constituents** | |
|---|---|
| Rubber | 36.0% |
| Filler (soot, $SiO_2$) | 37.0% |
| ZnO | 1.2% |
| Softeners | 3.0% |
| Sulfur | 1.3% |
| Steel, textiles | 18.0% |
| Rest | 3.5% |
| Total | 100% |

| **Chemical analysis** | |
|---|---|
| C | 70% |
| H | 7% |
| S | 1 ...3% |
| Cl | 0.2...0.6% |
| Fe | 15% |
| ZnO | 2% |
| $SiO_2$ + rest | 5% |
| Cr | 97 ppm |
| Ni | 77 ppm |
| Pb | 60 to 760 ppm |
| Cd | 5 to 10 ppm |
| Tl | 0.2 to 0.3 ppm |

Incineration in Cement Kilns

Incineration of waste tires in cement kilns has nowadays become a frequent method. At least 40 cement plants are known to do so. They can usually substitute 10 - 20% of their fuel requirements.

From an environmental point of view this method is considered as proven and advantageous (energetical recycling, low emission, no solid residues). It is often well accepted by the authorities.

Application of feeding methods:

1) Whole tires
This is the most frequent application, based on the secondary firing principle. Originally, this was first developed and used on dry SP-kilns but then also extended to long dry or wet kilns.

   a) Kiln inlet of suspension preheater kilns
   A feed system according to the figure 8 involves an investment of some USD 2 Mio. for a fully automatic installation.

   b) Mid kiln introduction device on long dry or wet kilns
   The principle is similar to a) but the introduction chute is rotating with the kiln shell, i.e. the tire feed is coupled with the kiln revolution. Figure 9 shows the introduction chute of the "Cadence" system as used at the Joliette plant.

2) Shredded tires / TDF
TDF = tire derived fuel

Shredded tires allow for a more regular fuel input into the kiln and have a higher density (advantages for transport and storage).

Shredding costs are some 30 - 60 UDS/t. Sometimes this is already paid by disposal fees. Shredding is normally not operated by the cement producer.

The use of shredded tires < 300 mm on suspension preheater kilns as in figure 10 is rare because it would cost less to use complete tires at the kiln inlet.

The use of shredded tires < 50 mm has some applications on long kilns in North America where still many long dry and wet kilns are in operation. The tire chips are injected into the burning zone. Figure 11 shows the example of the Seattle plant with 15% substitution. Shredded tires or TDF < 50 mm are successfully used on precalciners according to figure 12 in the plants Midlothian, Theodore, Ramos Arizpe and Lägerdorf.

3) Ground tires (< 5 mm):
Theoretically, ground tires would be the ideal fuel for any primary firing (without compromise). However, the costs for grinding are usually prohibitive. Ground rubber as granulate is normally too expensive as fuel. Nevertheless, a Group Plant in Germany and HCB have tried this and gone through a learning process.

4) Pyrolisis/Gazification of tires:
   The Japanese have realised gasifications for cement kilns and reported more than a decade ago. It was based on a reactor (shaft) with understochiometric air addition at 700°C. The hot gas produced was directly sent to the cement kiln.

   1999 a new gasifier for whole tires (industrial scale) was commissioned by Polysius at Jura Cement in Wildegg (Switzerland). The hot combustible gases are used in the precalciner. Investment for a 3 t/h installation is in the order of 3 Mio. USD. (Fig. 13)

   The gasification can potentially help to optimize the use of tires, which still needs to be demonstrated on a long-term basis. The costs are significantly higher than for burning the tires directly. Direct burning - not gasification - should always be the first option to be investigated.

**Fig. 8 Whole Tire Handling and Lump Fuel Kiln Feed (HCB-Eclépens)**

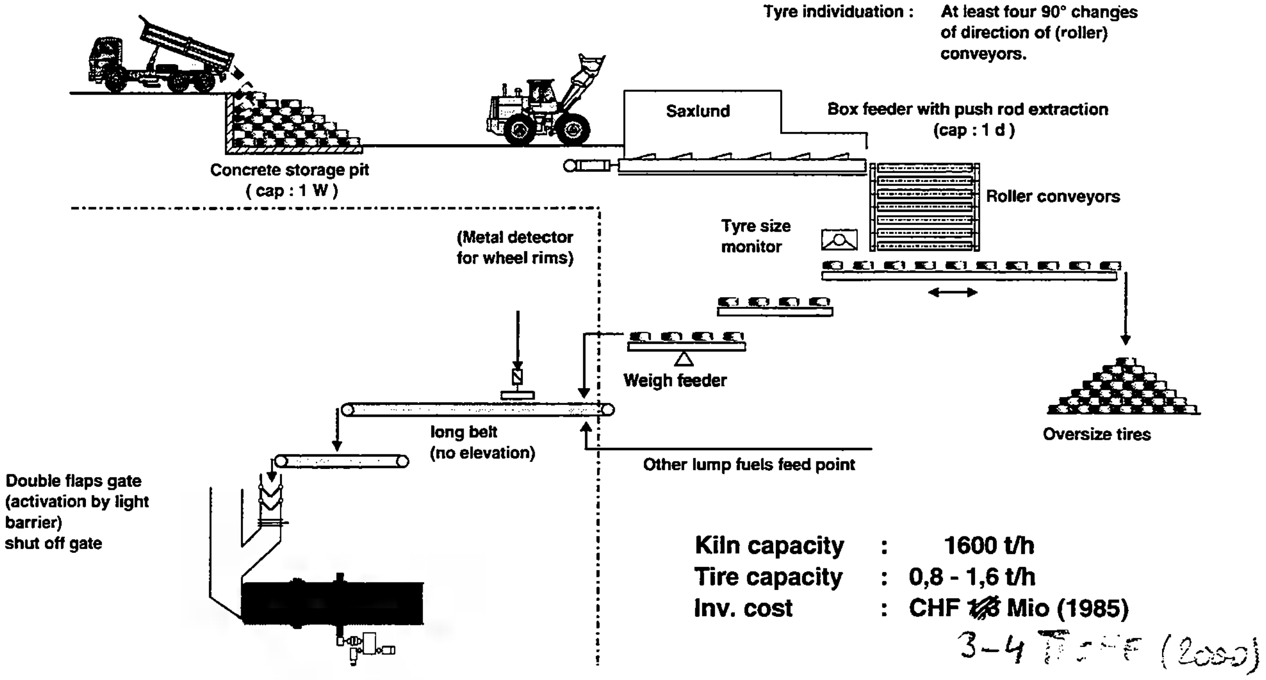


**Fig. 9 "Cadence valve" on Joliette kiln**

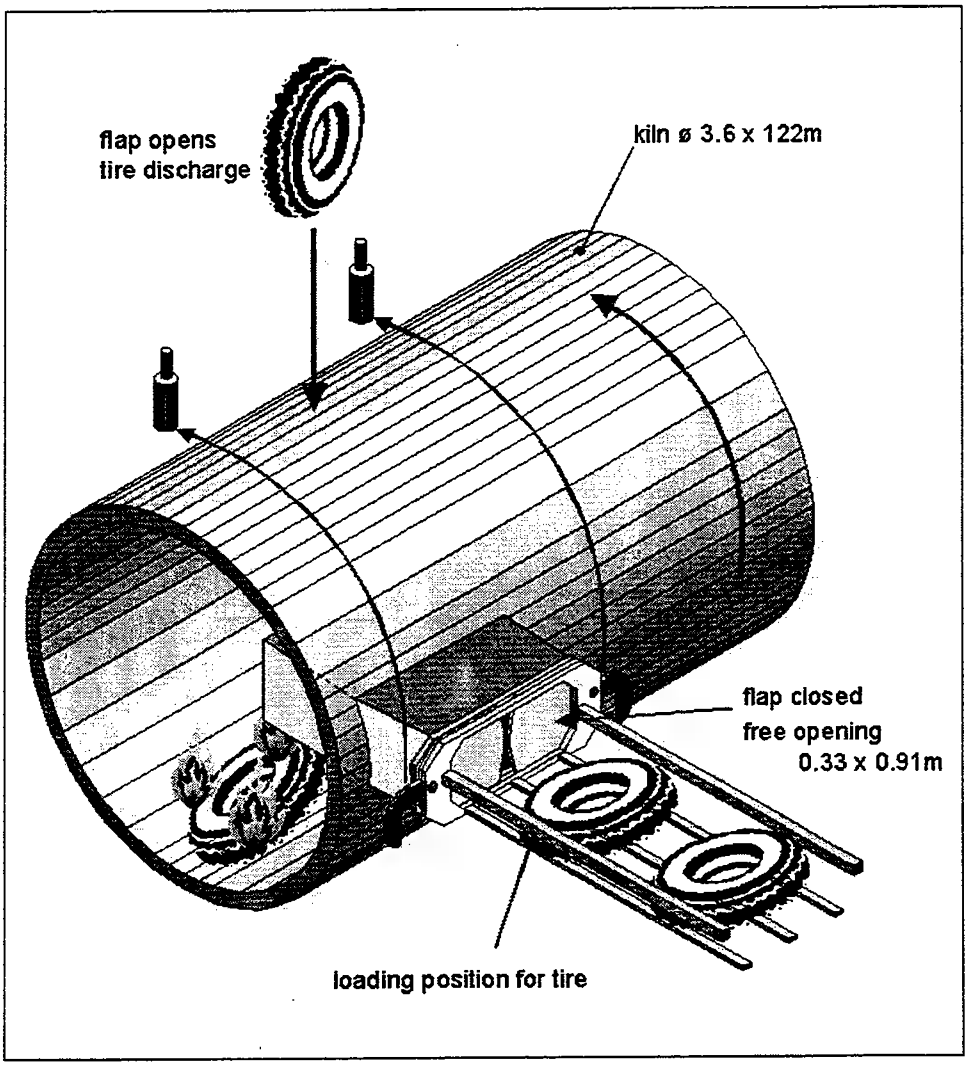
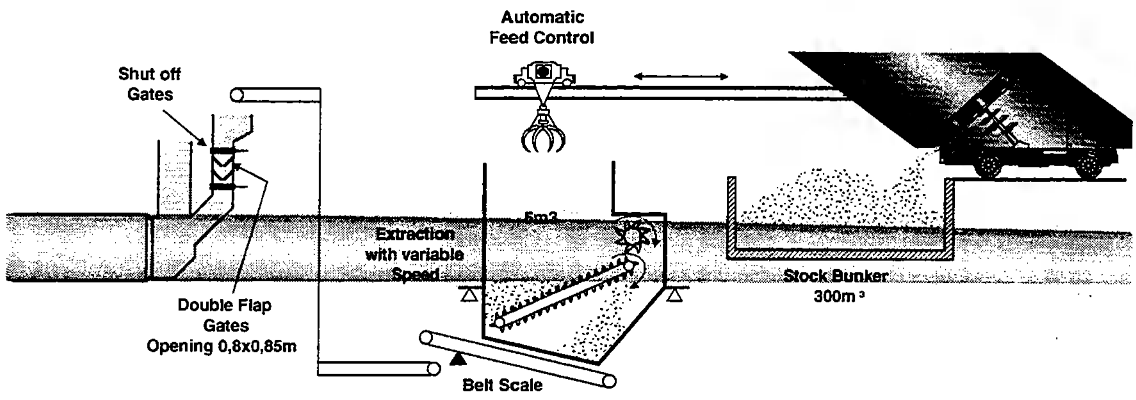
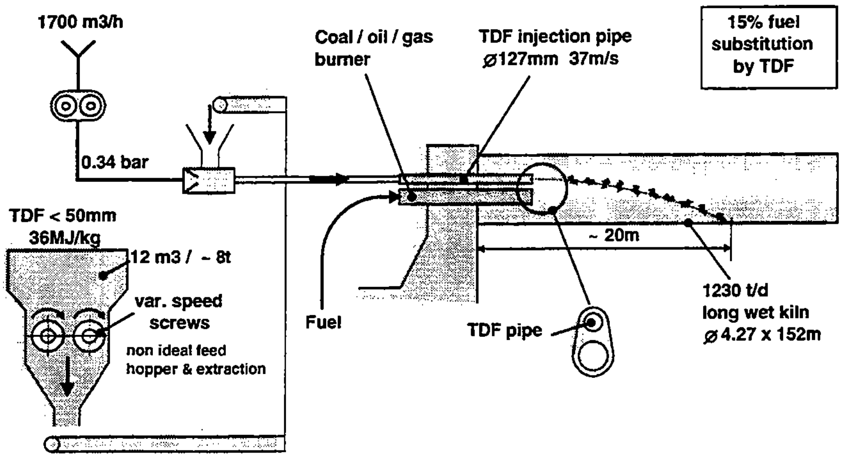


**Fig. 10** **Handling of Tyre Chips and Lump Alternative Fuels at Altkirch**

## Handling of Tyre Chips and Lump Alternative Fuel at ALTKIRCH



## Fig. 11 Burning of TDF ( Tire Derived Fuel) at the Seattle plant




## Fig. 12 Generic tire chip feeding system

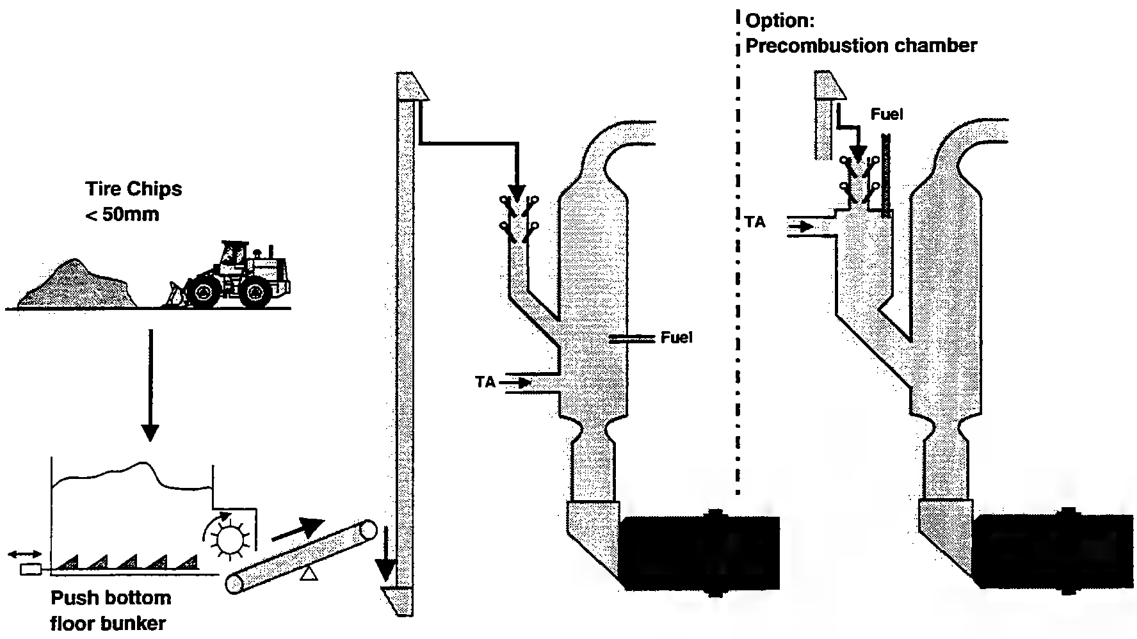
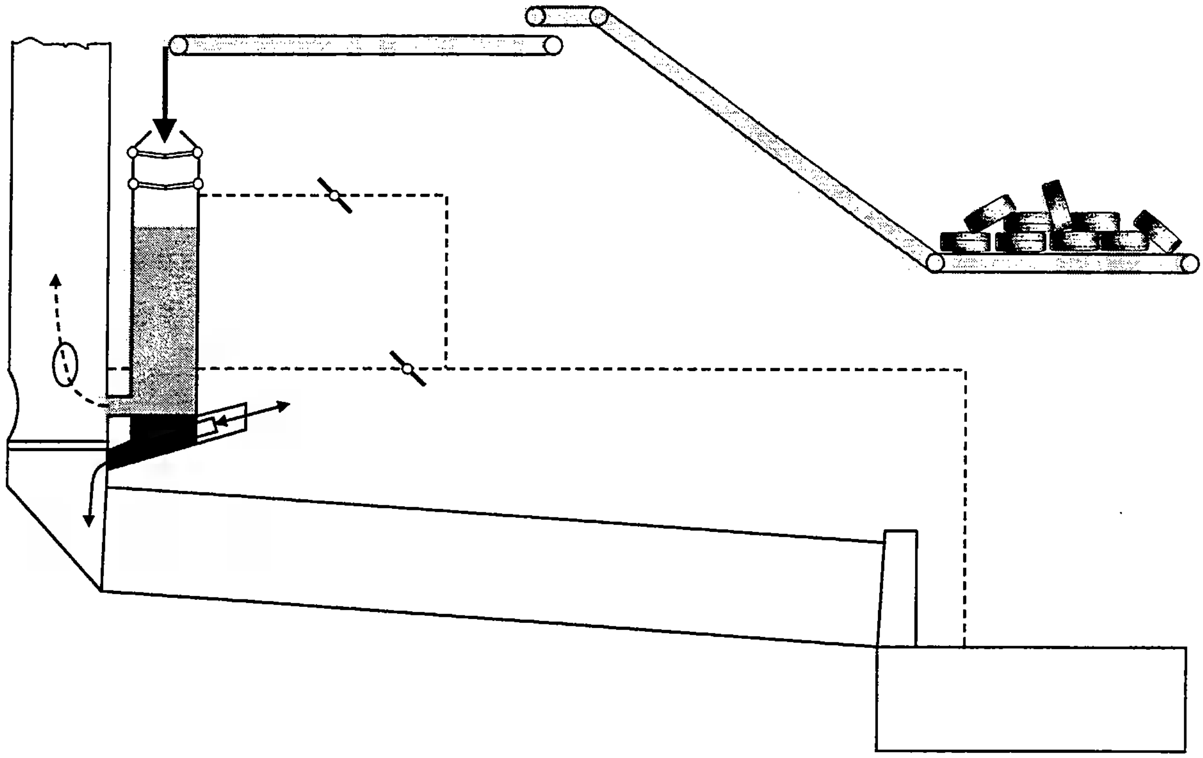


**Fig. 13 Integrated Gasifier (Polysius) for whole tires**



## 6.2 Domestic Refuse / RDF

- Example Germany:

| | Domestic refuse | Cement consumption |
|---|---|---|
| Quantity<br>Energy content (heat energy) | 400 kg/cap a<br>3.4 GJ/cap a | 450 kg/cap a<br>1.7 GJ/cap a |

- The energy content contained in the domestic refuse is twice the energy consumption of the cement!
- However, a complete use of the energy from raw domestic refuse in the cement industry is by no means feasible. Reasons:
  - poor homogeneity, inadequate size, difficult handling
  - Cl-content of 0.5...1% Cl which can cause clogging problems in the kiln
  - low calorific value (8 to 10 MJ/kg)
  - low density and high transport costs per heat unit
  - competition to existing incinerators

Conclusion:

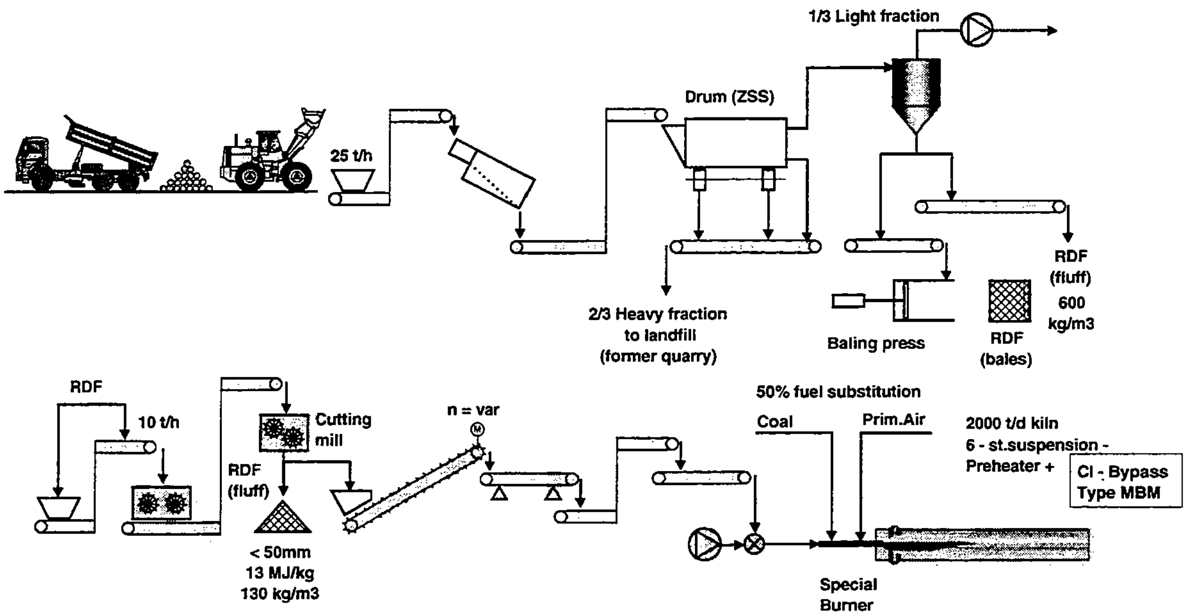
Domestic refuse needs intensive processing in order to eliminate undesired fractions and to obtain a reasonable burnable fraction. Such a fraction may represent 30...50% of the original refuse, the rest needs further disposal. The burnable fraction is called RDF (refuse derived fuel) and offers somewhat better properties, e.g. a CV of 12...16 MJ/kg.

Experience:

The first application was in the early 80's at BCI/Westbury, now stopped.

The most important application today is the Wittekind plant in Erwitte (Germany) according to figure 14 with 50% substitution and a chlorine bypass. Otherwise very few plants have realized major applications.

## Fig. 14 Processing of Domestic Refuse and Incineration of RDF in a SP Kiln




Example of the 2000 t/d suspension preheater kiln of Wittekind in Erwitte (Germany)

## 6.3 Burning of Contaminated Waste Oil

The burning of waste oil in cement kilns has a long tradition. In the late 80's and early 90's new efforts have been made to investigate the influence of contaminants. Extensive measurement programs have been performed to demonstrate all possible impacts on the environment.

Important examples come from Germany and Austria.

One of the first plants to publish the results of its measurements in 1988 was Phoenix in Beckum/Germany. They burnt waste oil, which was contaminated with PCB (0 to 1000 ppm). Emissions of dioxins were also measured. This project was 50% sponsored by the German Umweltbundesamt (UBA).

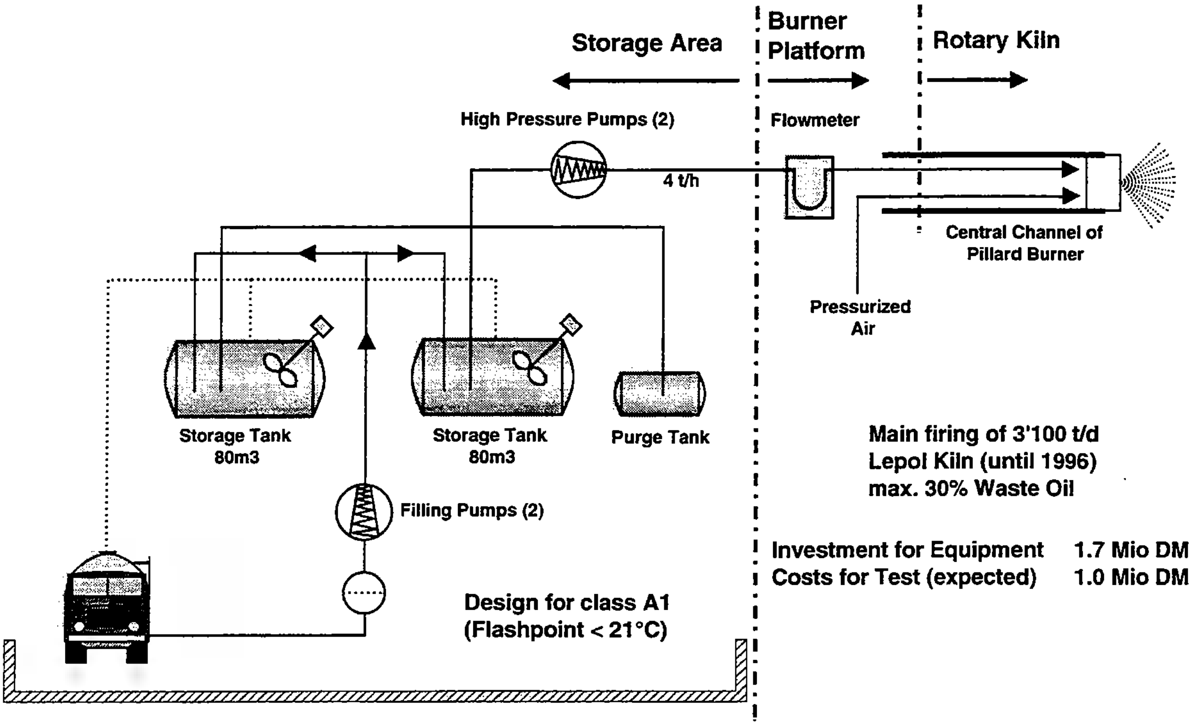
The Lägerdorf plant and the Gmunden plant (Austria) have also followed this at an even higher degree of perfection. The design of the original Lägerdorf installation is shown in the figure 15. A large program of measurements has been done and published. This program also includes emission measurements of $SO_2$, NOx, heavy metals, F, chlorinated organics, PCB, Dioxins/Furans. It could be demonstrated that a limit for dioxins of 0.1 ng TE/m$^3$ (toxic equivalent) could be easily met and that these emissions are not influenced by burning contaminated waste oils. A similar result was obtained at Gmunden.

Special efforts were also made with regard to the delivery control, which meant a considerable extension to the existing laboratory. Limiting values for the waste oil in Gmunden:

| | | |
|---|---|---|
| Pb | < | 5000 ppm |
| Hg | < | 2 ppm |
| Tl | < | 10 ppm |
| Cd | < | 60 ppm |
| PCB | < | 100 ppm |
| F | < | 600 ppm |
| S | < | 5% |
| Cl | < | 1% |
| N | < | 5% |
| $H_2O$ | < | 15% |
| Sediments | < | 5% |
| CV net | > | 25'000 kJ/kg |

The original installation Lägerdorf according to figure 15 is designed for low flashpoints (< 21°C), therefore, use of solvents is also possible.

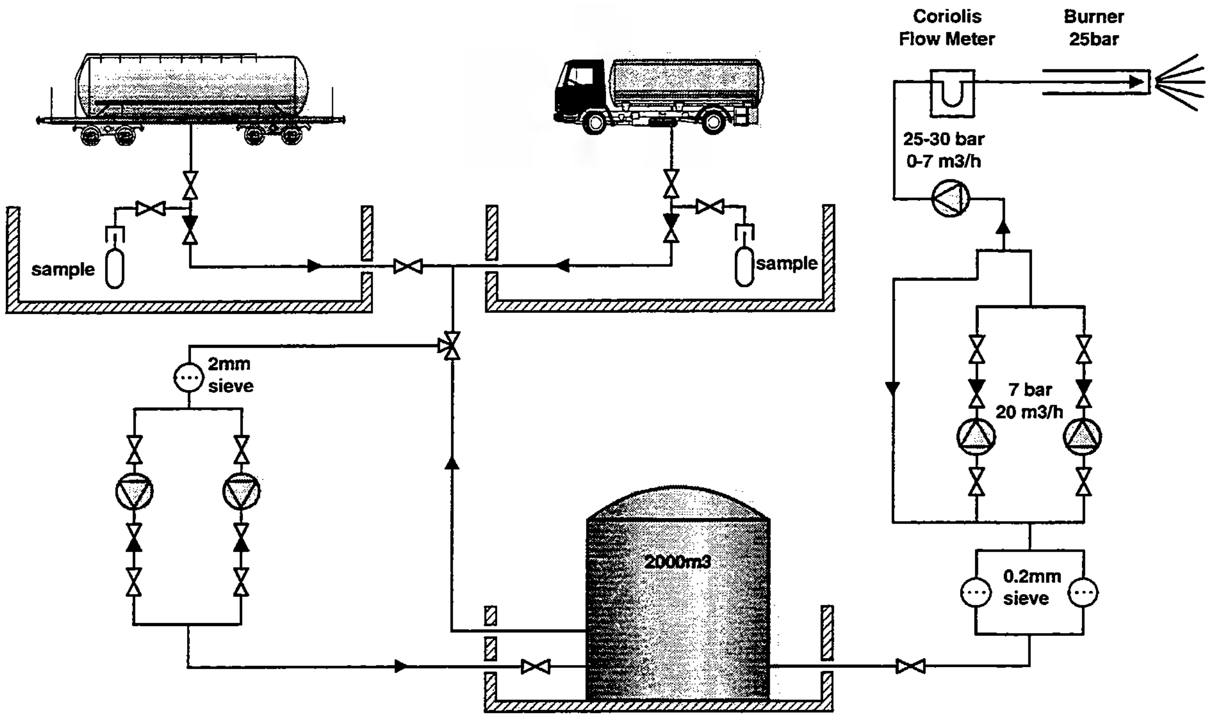
## Fig. 15 Burning of Waste Oil at Lägerdorf Plant



### 6.4 Burning pure waste oil

The installation from Untervaz according to figure 16 results from a former heavy oil system and is adequate for high quality waste oil with high flashpoint (> 55°C).

**Fig. 16 Handling of Waste Oil at BCU Untervaz**

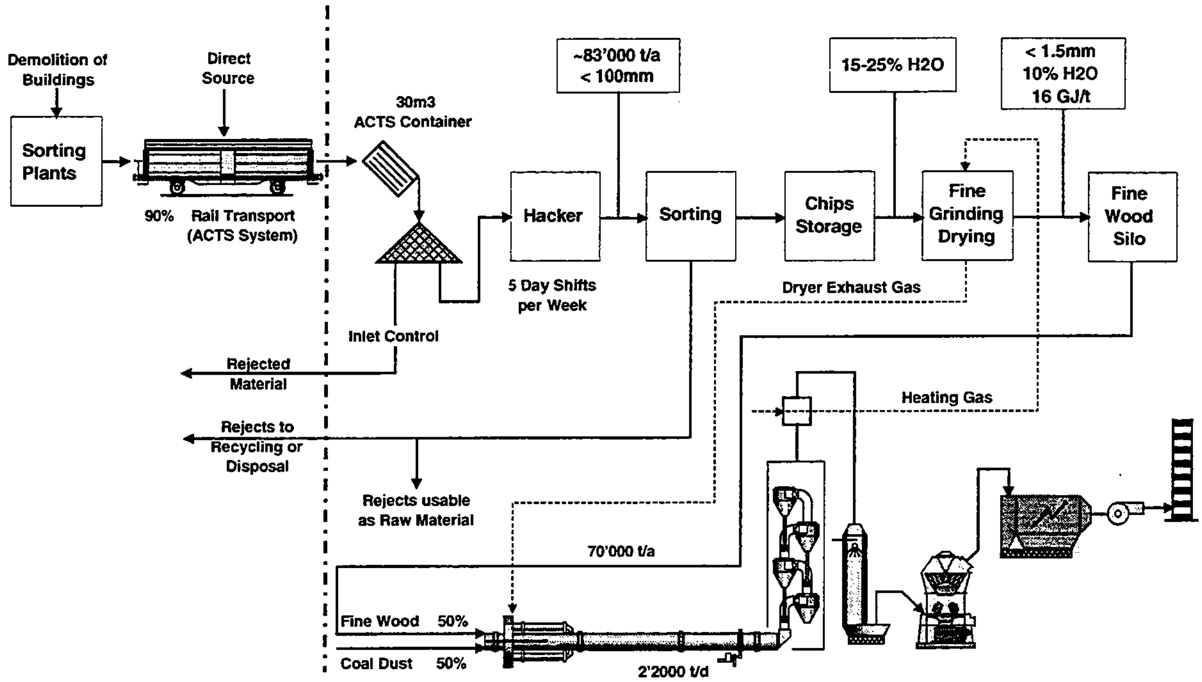



### 6.5 Burning of Waste Wood at Rekingen

This installation to process waste wood to a dry saw dust and burn it in a cement kiln went into operation in 1994. It was stopped in 1997 because the Rekingen plant was closed (market reasons). The final stage of this project would have been 70'000 t/a of processed waste wood or 50% fuel substitution. The treatment of the incoming wood consisted of delivery control, primary crushing, sorting fine grinding and drying.

The projected costs were 25 Mio. Swiss Francs and therefore among the highest ever realized for a single project for an AF. During the project phase the fees for waste wood were overestimated. When it came into operation, the actual market prices for waste wood were much lower and the installation could not be amortized.

**Fig. 17** **Use of Waste Wood as Fuel at the Rekingen Plant**




Note: Data as indicated refer to original project design

## 6.6 Mixed examples

The following illustrations originate from our reports describing practical AFR applications in our Group plants. The illustrations are self-explaining.

Content:

- Liquid AF at Altkirch
- Liquid AF at Obourg
- Distillation Residues and Animal Fat at Untervaz
- Mid kiln firing for bales at Obourg
- Dried Sewage Sludge and Animal Meal at Untervaz
- Solid AF (Impregnated saw dust) at Eclépens
- Tire Chips and Ferrocarbon at Lägerdorf
- Fly ash at Lägerdorf

**Fig. 18 Handling of Liquid Alternative Fuels (CSL) at Altkirch (Solvents, Oil-Emulsions, Pasty Liquids)**

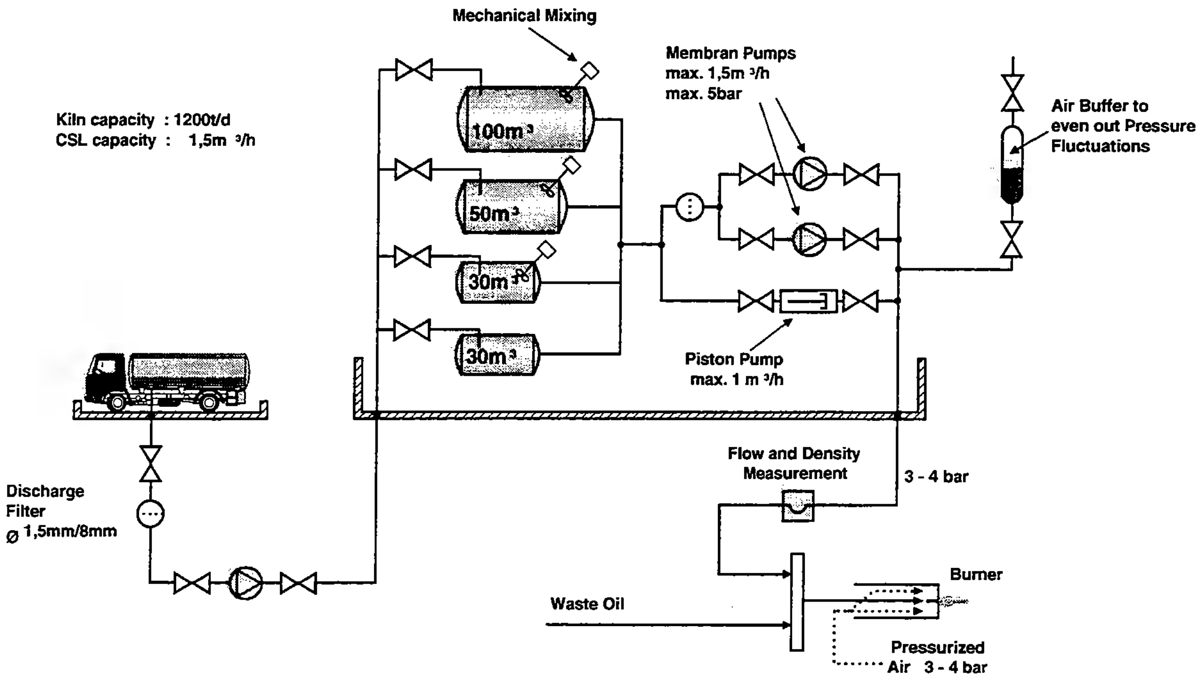


**Fig. 19 Handling of Solvents (CSL: Combustible de Substitution Liquide) at Ciments d'Obourg**

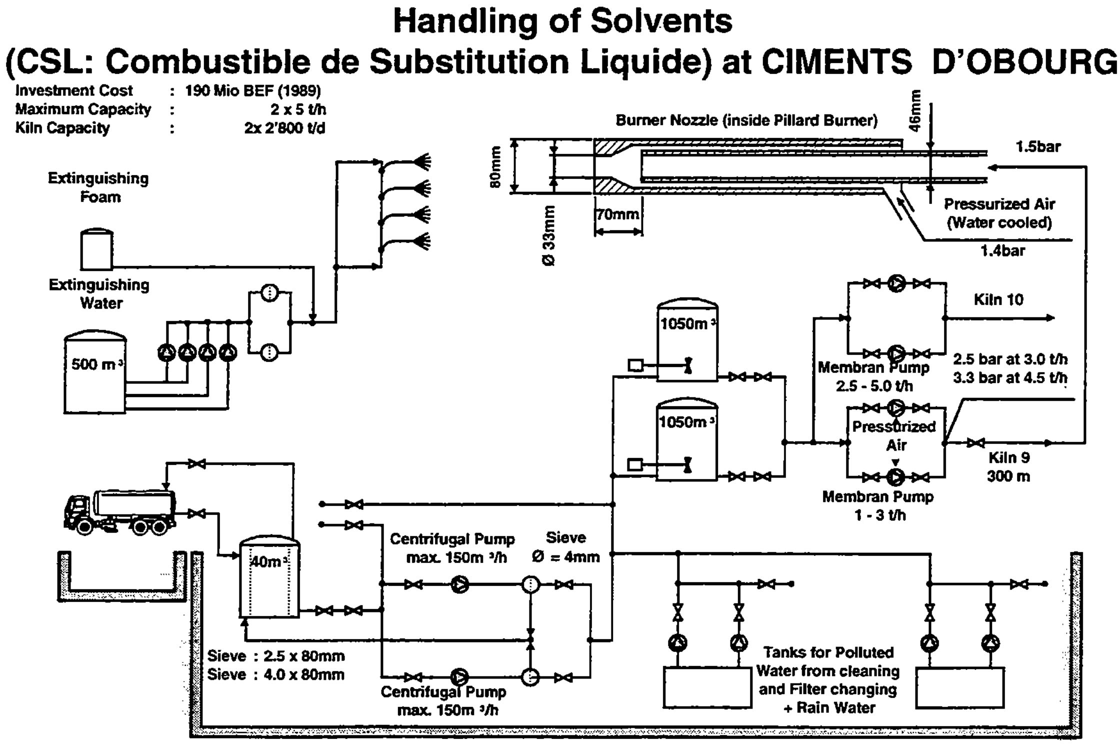


**Fig. 20** **Handling of Destillation Residue and Animal Fat at BCU Untervaz**

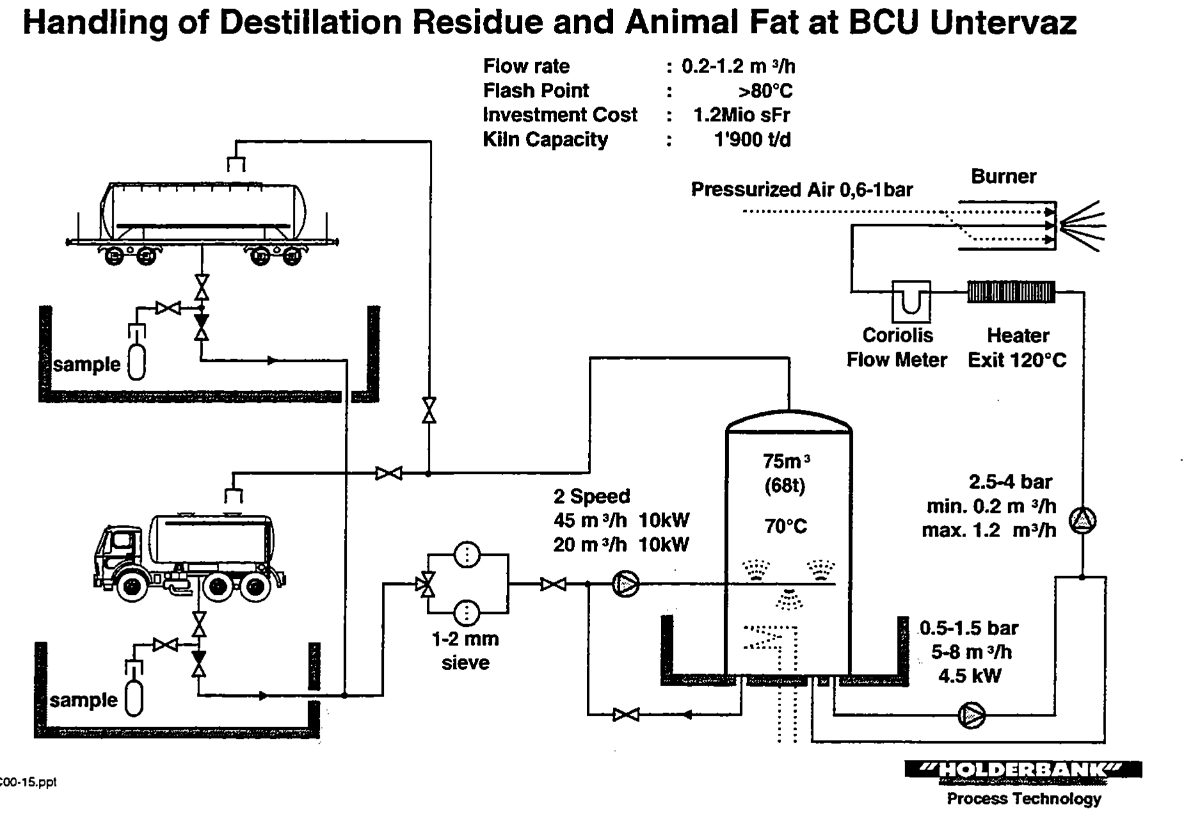
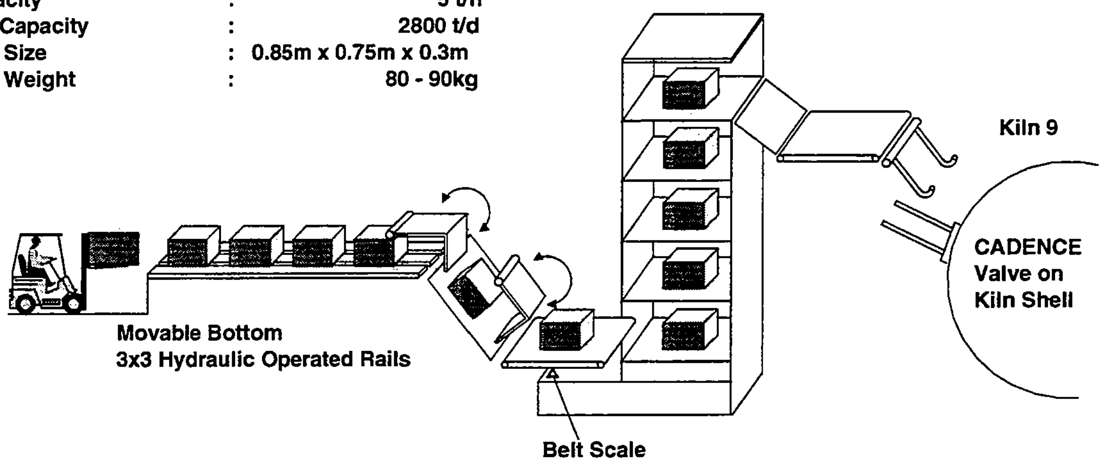


**Fig. 21** **Mid Kiln Installation at Ciments d'Obourg**

## Mid Kiln Installation at CIMENTS D'OBOURG

| | | |
|---|---|---|
| Investment Cost | : | 30 Mio BEF (1996) |
| Capacity | : | 5 t/h |
| Kiln Capacity | : | 2800 t/d |
| Bale Size | : | 0.85m x 0.75m x 0.3m |
| Bale Weight | : | 80 - 90kg |

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"HOLDERBANK"
Process Technology

**Fig. 22** **Handling of Dried Sewage Sludge and Animal Meal at Untervaz**

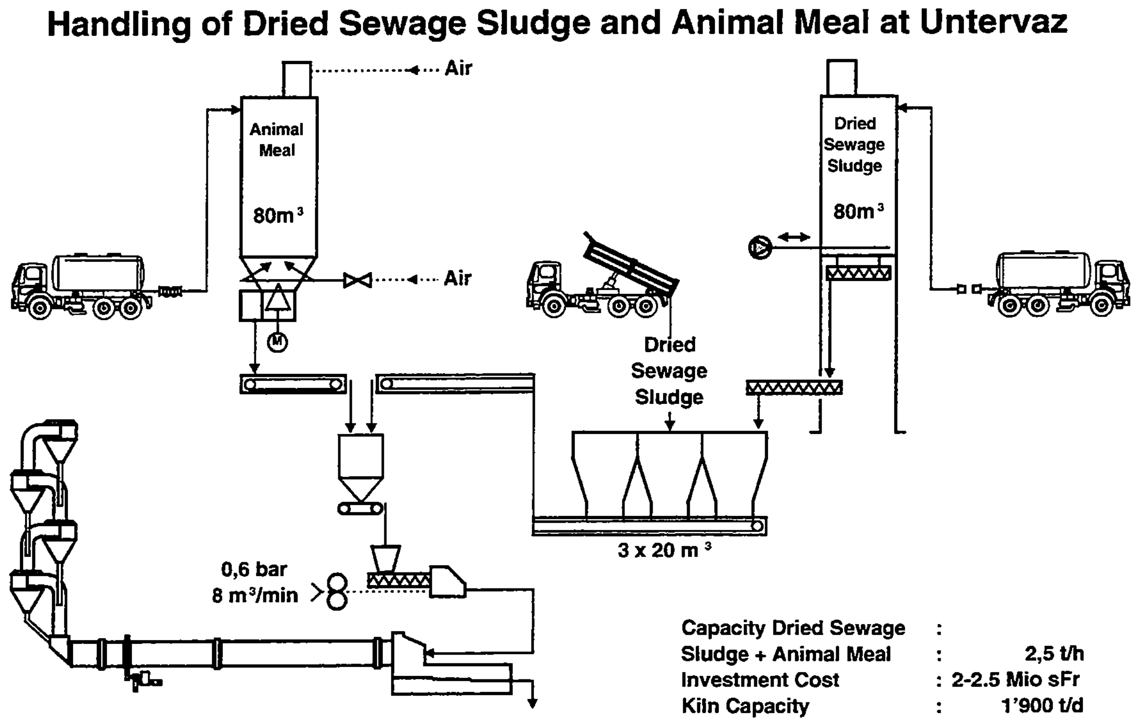
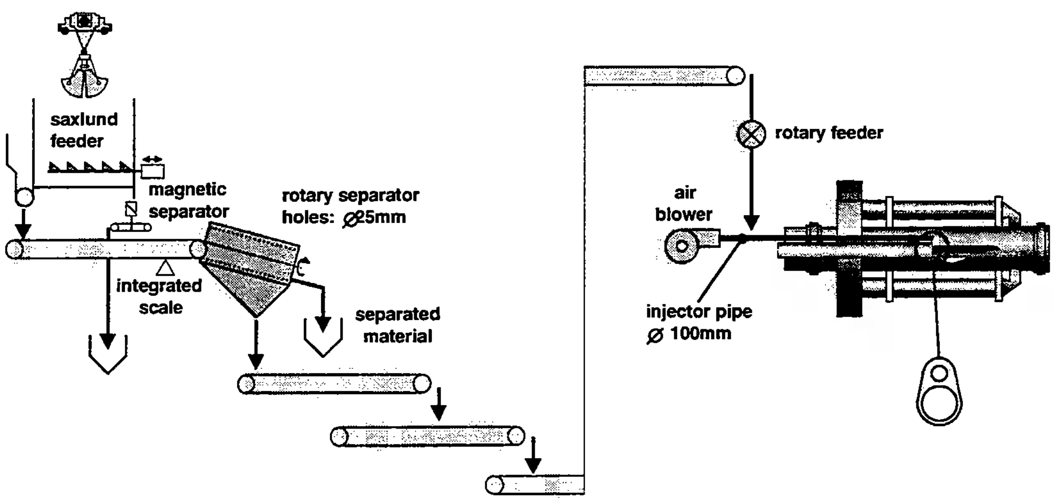



**Fig. 23** **Handling and injecting of solid fuel at "HCB Eclépens (impregnated saw dust, shredded plastic, animal meal)**



## Fig. 24 Handling of Tire Chips and Ferrocarbon at Lägerdorf

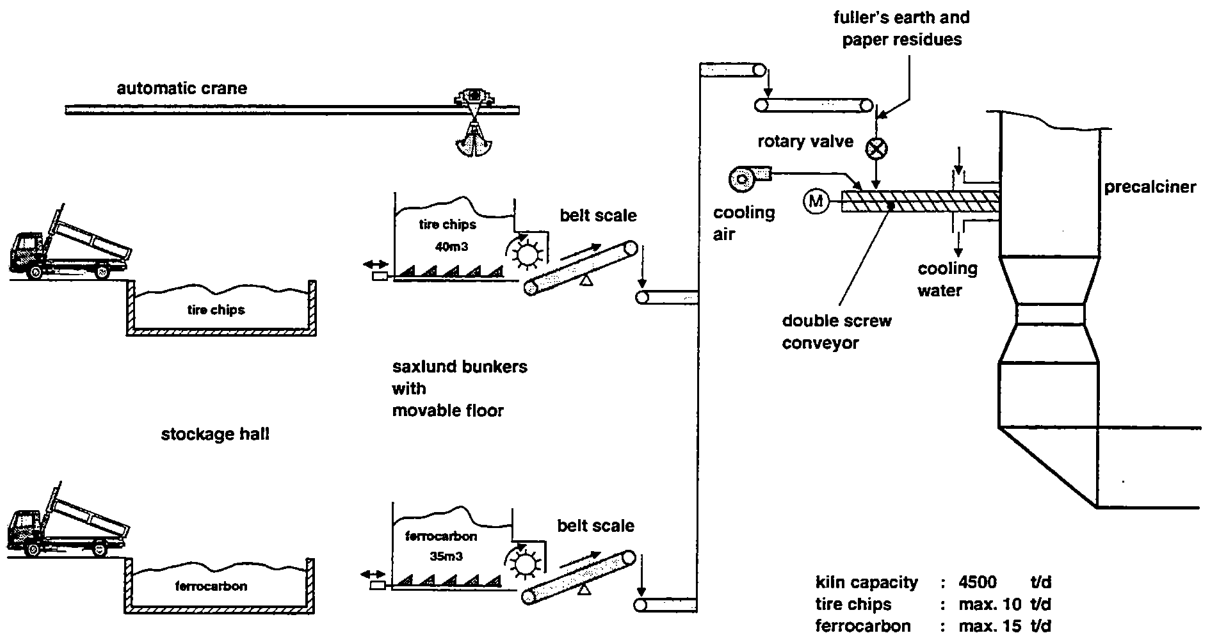


**Fig. 25** **Handling of fly ash at Lägerdorf**